ECOLOGY AND CONSERVATION OF AN ENDANGERED REPTILE COMMUNITY ON ROUND ISLAND, MAURITIUS

Dissertation

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THIS THESIS IS DEDICATED TO CHRISTINE, MY PARENTS, MY FAMILY, MY FRIENDS AND EVERYONE WHO BELIEVED IN ME
FOR THEIR LOVE, HELP AND SUPPORT,
WITHOUT THEM I WOULD HAVE ACHIEVED NOTHING

CONTENTS

CHAPTER 1

General introduction

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General introduction

Since the birth of the volcanic island of Mauritius 8 millions years ago, its flora and fauna has evolved in isolation due to the island's remoteness from large land masses (Fig. 1). Consequently, Mauritius harbours unique endemic plant communities and a disharmonic fauna in which birds and reptiles take key positions (Myers *et al*. 2000). With the exception of bats, no mammals reached the island unaided. As a result, birds and reptiles performed key ecosystem functions, such as grazing, seed dispersal and pollination (Cheke & Hume 2008).

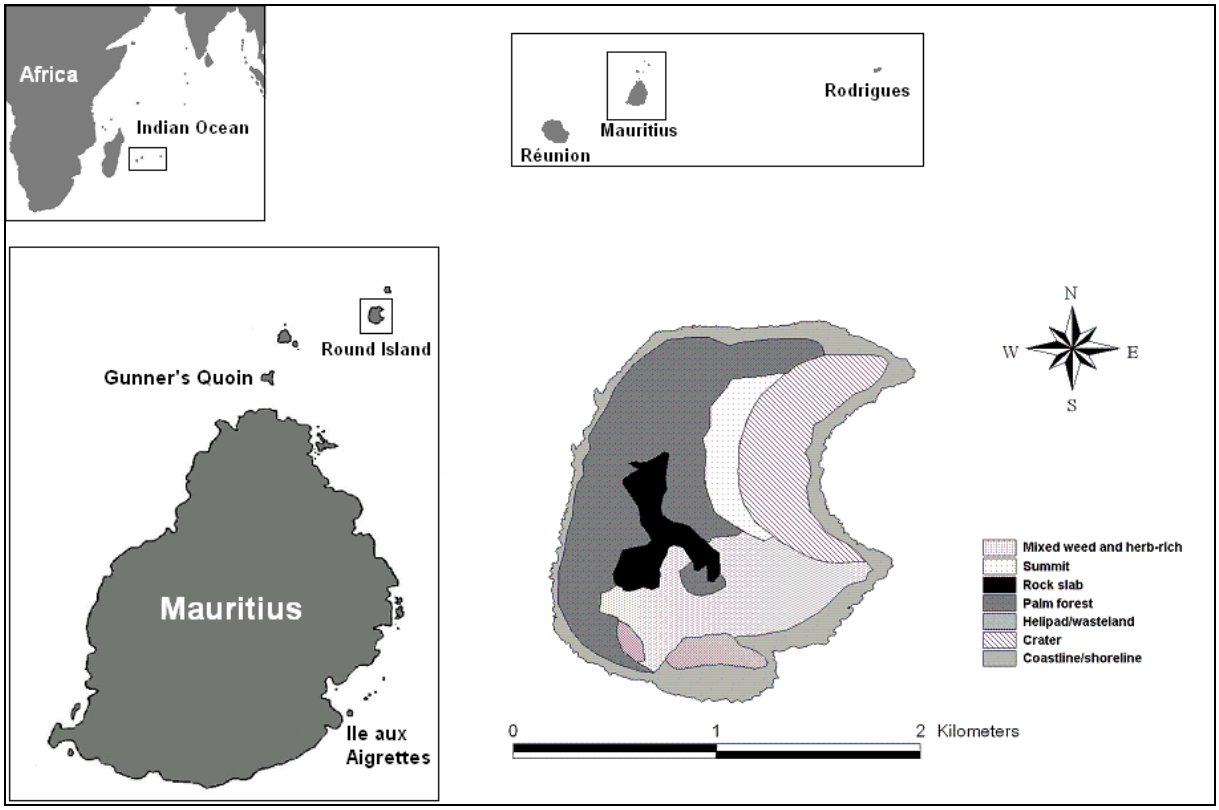

Figure 1. The Mascarene archipelago (Mauritius, Réunion and Rodrigues) is located in the south-western Indian Ocean. Mauritius (1865 km²) and selected offshore islands are situated 830 km east of Madagascar, between 19°50'S and 20°51'S, and 57°18' and 57°48'E. Round Island, a northern offshore island of Mauritius, is composed of seven different habitats and is where this study was conducted.

Unfortunately, over the past 400 years Mauritian ecosystems have been heavily degraded (Cheke & Hume 2008). Initially, overexploitation of particular species caused a series of plant and animal extinctions. Forests and natural habitats were destroyed. Today, only about 2% of original native forest persists (Vaughan & Wiehe 1937). Most notably, Mauritius has lost its large land vertebrates: two giant land tortoises (*Cylindraspis inepta* and

C. triserrata), a large flightless parrot (*Lophopsittacus mauritianus),* the dodo (*Raphus cucullatus*), a giant skink (*Leiolopisma mauritianus*) and a fruit bat (*Pteropus subniger*) (Cheke & Hume 2008). As a result of these extinctions, many co-evolved plant – animal interactions were disrupted, which may have led to lost ecosystem services and functions (Arnold 1979; Olesen & Valido 2003). The surviving plant species which evolved traits in response to extinct partners are likely to be suffering this legacy (Janzen & Martin 1982). Many of the endemic and native flora are critically endangered and continue to be threatened with extinction. For example, of the 680 original native and endemic plant species in Mauritius, some 80 are already extinct, and 155 are critically endangered. In fact, 79 of the critically endangered species are represented by less than ten known individuals, and 12 of these are represented by only a single known individual. A further 93 species are endangered and 241 vulnerable, making 82% of the native flora and 94% of the endemic flora of Mauritius threatened according to IUCN criteria (Mauritian Wildlife Foundation, unpublished data) The greatest prevailing threats are from competition with exotic invasive plant and animal species (Cheke & Hume 2008; Strahm 1993).

Today, most of the native fauna and flora are restricted to mountain tops, cliffs, conservation management areas (CMAs), and offshore islands. Despite their often small size, some of these islands support many endemic, threatened species, and hence are of significant conservation value (Jones 1993). One such island is Round Island, with an area of about 219 ha and an altitude of 280 m (Johansson 2003), situated 22.5 km north of Mauritius (Fig. 1). Round Island has never been invaded by rats and hence has retained most of its reptile community (Arnold 2000). Consequently, it is also one of the most important seabird islands in the western Indian Ocean (North *et al*. 1994).

The Round Island herpetofauna is outstanding: Eight species have been recorded, of which seven are Mascarene (Mauritius, Réunion and Rodrigues) endemics and four are now confined to Round Island (North *et al*. 1994; Vinson 1975). However, the Burrowing boa, *Bolyeria multocarinata*, which was last seen in 1975, is probably extinct (North *et al*. 1994). Early reports indicated that two species of giant tortoises (*Cylindraspis* sp.) were present but went extinct around the 1800 (Cheke & Hume 2008).

The Round island herpetofauna is composed of three skinks: Telfair's skink (*Leiolopisma telfairii)*, Bojer's skink (*Gongylomorphus bojeri*) and Bouton's skink (*Cryptoblepharus boutonii*); three geckos: Guenther's gecko (*Phelsuma guentheri*), Ornate day gecko (Vinson's gecko) (*Phelsuma ornata*) and the Durrells' night gecko (*Nactus durrelli*); and two snakes (boa): Keel-scaled boa (*Casarea dussumerii*) and Burrowing boa

(*Bolyeria multocarinata*). Tables 1 and 2 provide information on the morphometrics and diet of the Round Island adult and juvenile reptiles of each species.

Table 1. Morphometrics of the seven Round Island reptiles collected over a period of one year from the seven different habitat types. Where SVL = Snout to vent length, tL = tail length, and TL = total length. Criteria is the length of the SVL (mm) to distinguish between adult and juvenile animals of a species, based on Bullock and North (1986) classifications. Adult and juvenile boa were categorised by colour, whereby orange boa are juvenile. Vinson (1975) found no difference in size attributed to sex. The values given are the mean value with the standard deviation in brackets.

Reptile species	Age	N	SVL (mm)	tL (mm)	TL (mm)	Weight (g)	Criteria (mm)
Telfair's skink	Adult	778	130.0 (±15.9)	146.9 (±32.2)	276.9 (±39.2)	67.5 (±28.3)	100.0
Telfair's skink	Juvenile	653	74.2 (±16.2)	101.2 (±30.0)	175.4 (±41.3)	12.5 (±8.7)	
Bojer's skink	Adult	782	56.4 (±7.4)	52.0 (±13.8)	108.4 (±17.0)	4.4 (±2.2)	35.0
Bojer's skink	Juvenile	331	34.6 (±4.5)	33.8 (±11.4)	68.4 (±13.4)	1.0 (±0.6)	
Bouton's skink	Adult	72	38.4 (±3.6)	46.7 (±11.9)	85.2 (±13.5)	1.3 (±1.1)	35.0
Bouton's skink	Juvenile	16	30.1 (±3.6)	29.3 (±11.1)	59.3 (±12.1)	0.6 (±0.2)	
Ornate day gecko	Adult	511	49.1 (±4.9)	48.9 (±11.5)	98.0 (±13.7)	3.5 (±1.1)	35.0
Ornate day gecko	Juvenile	266	32.7 (±4.8)	33.5 (±8.8)	66.1 (±12.5)	1.2 (±0.6)	
Guenther's gecko	Adult	182	115.8 (±10.1)	111.3 (±22.9)	227.1 (±28.2)	54.4 (±15.4)	100.0
Guenther's gecko	Juvenile	73	74.3 (±18.3)	69.2 (±24.2)	143.4 (±38.8)	15.7 (±11.5)	
Durrells' night gecko	Adult	425	49.0 (±5.8)	35.7 (±12.4)	84.8 (±14.1)	3.2 (±1.1)	35.0
Durrells' night gecko	Juvenile	48	33.5 (±15.9)	31.2 (±9.8)	64.7 (±12.0)	1.0 (±0.5)	
Keel-scaled boa	Adult	188	698.9 (±206.7)	239.8 (±65.0)	938.7 (±260.1)	198.6 (±148.3)	Colour
Keel-scaled boa	Juvenile	90	259.0 (±87.7)	94.3 (±31.6)	353.3 (±115.8)	11.3 (±18.6)	

Table 2. The percentage occurrence of plant, invertebrate, reptile and bird origin in the diet of the seven Round Island reptile species at the adult and juvenile stages over a period of one year from the seven different habitat types. Data was collected from 4311 faecal samples

Reptile species	Age	N	Plants	Invertebrates	Reptiles	Birds
Telfair's skink	Adult	843	19.9	75.1	2.3	2.7
Telfair's skink	Juvenile	655	5.7	93	0.7	0.6
Bojer's skink	Adult	776	1.1	98.4	0.3	0.2
Bojer's skink	Juvenile	306	0.3	99.7	0	0
Bouton's skink	Adult	66	0	100	0	0
Bouton's skink	Juvenile	12	0	100	0	0
Ornate day gecko	Adult	469	6.9	92.9	0.3	0
Ornate day gecko	Juvenile	239	6.1	93.9	0	0
Guenther's gecko	Adult	176	7.1	86	6.2	0.8
Guenther's gecko	Juvenile	71	3.3	96.2	0.5	0
Durrells' night gecko	Adult	405	0	100	0	0
Durrells' night gecko	Juvenile	38	0	100	0	0
Keel-scaled boa	Adult	176	0	0	93	7
Keel-scaled boa	Juvenile	79	0	0	100	0

The largest extant endemic Mauritian skink, the Telfair's skink (*Leiolopisma telfairii,* Desjardins, 1831) (Jones 1993), was restricted to Round Island until recently when it was translocated to Ile aux Aigrettes and Gunner's Quoin. The adult and the juvenile are similar in appearance; the body is general brownish grey and mottled with dark brown spots. The skink is largely diurnal and terrestrial (Bullock 1986). However, it is also active at night and arboreal when consuming fruits and flowers (Jones 1993). The adults mate in July to August. From October to December, females deposit an average of 4 to 16 eggs at a time in soft earth and seabird burrows (Bloxam 1976), which are plentiful in some areas of Round Island. The young hatch from January to March. They occur in a wide range of habitats on the island: forests, grasslands, sparse creeper covered ground to bare rock with crevices and rock piles (Vinson 1975). Extensive feeding observations and faecal analyses indicate that they are omnivorous (Table 2). Cannibalism has been observed.

The Bojer's skink (*Gongylomorphus bojeri,* Desjardins, 1831) is an endemic medium sized skink compared to other reptiles species worldwide (Jones 1993). The adult and the juvenile are alike; the body is generally golden brown to greyish-brown, with a lighter grey to white underside (Bullock 1986). The adults mate in July to August. From October to December, females lay two eggs at a time in the soft earth and beneath logs (Vinson 1975). The young hatch from January to March. They have sympatric habitats to the Telfair's skink (Vinson 1975). There smaller size restricts these terrestrial lizards to a diurnal lifestyle. Bojer's skinks feed mostly on invertebrates. Other smaller reptiles, fruits and carrion are also consumed (Table 2). Cannibalism has been observed.

The Bouton's skink (*Cryptoblepharus boutonii,* Desjardins, 1831) is a pan-tropical small sized skink (Jones 1993). The adult and the juvenile are generally dark-brown with dark grey to black speckles and their underside a light grey (Vinson 1975). They are restricted to coastal rocky habitats (Vinson 1975). The adults mate in July to August. From October to December, the females deposit 2 eggs at a time in rock crevices (Bullock 1986). The young hatch from January to April. This diurnal terrestrial lizard feeds mostly on invertebrates (Table 2), but they will also eat marine crustaceans and occasionally small fish, which they predate from rock pools and the splash zone (Bullock 1986; Jones 1993; Vinson & Vinson 1969).

The Guenther's gecko (*Phelsuma guentheri,* Boulenger, 1885) is an endemic large sized gecko (Vinson 1975). The juvenile has darker markings on its back and tail, whereas the body of the adult is generally pale greyish-brown. Colouration does vary with temperature and behaviour, from pale green to dark patterned brown to copper. The underside varies from

pale whitish-grey to dark brown. Adult males have bright yellow pores around the vent (Vinson 1975). The adults mate in July to August. From September to March, the females deposit 2 eggs at a time, which are glued into position and are often laid in communal nesting sites on the sheltered trunks of trees or on the underside of rocky coves (Carpenter *et al.* 2003). The young hatch from December to May. They are found mainly in *Latania* palms and *Pandanus* trees, but are also frequently seen in open rocky areas and on gully walls (Vinson 1975). This predominantly arboreal lizard is diurnal-nocturnal, whose activity is dependent on the temperature (Bullock 1986). Guenther's gecko feed mostly on invertebrates, but they will also consume other smaller reptiles, eggs, nectar and tree resin (Table 2).

The Ornate day gecko (*Phelsuma ornata,* Gray, 1825) is an endemic medium sized gecko (Vinson 1975). The adult and the juvenile are similar in appearance; their dorsal body is generally greenish-brown to bluish-green with a row of paired red spots down the back. Their underside is pale creamy-white, with bright yellow pores/spots around the vent of adult males (Vinson 1975). The adults mate in July to August. From September to March, the females often lay 2 eggs at a time in communal nesting sites within rocky crevices, cavities and on sheltered vegetation (Vinson 1975). The young hatch from December to May. This predominantly arboreal gecko is frequently spotted in vegetation, particularly *Pandanus* trees and palms, as well as in open rocky habitats (Vinson & Vinson 1969). Though mainly a diurnal lizard, it has also been seen foraging at night (pers. obsv.). Their diet consists of mostly invertebrates, but they will also feed on fruit, nectar and tree resin (Table 2).

The Durrells' night gecko (*Nactus durrelli,* Arnold, 1994) is an endemic medium sized gecko (Vinson 1975). Their body is generally brown to orange-brown with darker spots and a white underside (Vinson 1975). The adults mate in August to September. From November to March, the females deposit 1 egg at a time within leaf litter, under rocks or in rock crevices and cavities (Vinson 1975). The young hatch from January to May. They are terrestrial nocturnal lizards, which occur in creviced gully walls, rocky outcrops and rock piles, but can also found in high numbers within the dense leaf litter in the island's palm savannah (Vinson 1975). They feed exclusively on small invertebrates (Table 2)(Bullock 1986; Vinson & Vinson 1969).

The Keel-scaled boa (*Casarea dussumerii*) is an endemic medium sized snake. The adult body generally varies between pale to dark greyish-brown, dark brown to a dull greenish-brown with a cream to white underside (Vinson 1975). The juveniles are bright orange or brick red (Vinson 1975). The adults mate in August to October. Females lay about 8 to 15 eggs (pers. comm. A. McMillan), but it remains a mystery as to where they are laid. It

is suspected that they probably bury their eggs in deep, loose soil and/or within rocky crevices. The young hatch from March to May. The adults are predominantly terrestrial, although do occasionally climb the palms to feed and take refuge. Juveniles are mostly arboreal and frequently use the lower branches of scrub or palm fronds to escape predation from the Telfair's skink. They are mostly nocturnal and feed upon the abundant skinks, geckos and occasionally seabird chicks, overpowering their prey by biting hold and constricting (Table 2).

The Burrowing boa (*Bolyeria multocarinata*) is an endemic medium sized snake of about 85 cm in length (Vinson 1975). It was last seen on Round Island in 1975 and is now most likely extinct (North *et al*. 1994). The body colour was typically dark brown, with lighter brown markings down the back and tail, and a lighter underside. They were assumed to be a burrowing species from their head shape, and probably lived in the loose soil and deep leaf litter piles where they would have predated upon the numerous small skinks and geckos (Bullock 1986; Vinson 1975).

Round Island also harbours the largest remaining area of palm forest that once dominated the lowlands of north and west Mauritius (Vaughan & Wiehe 1937). This palm forest is composed of the rare endemic fan palm (*Latania loddigesii*), a native screwpine (*Pandanus vandermeerschii*), an aloe (*Lomatophyllum tormentorii*), the bottle palm (*Hyophorbe lagenicaulis*) and the only remaining mature hurricane palm (*Dictyosperma album* var. *conjugatum*).

Unfortunately, goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*) which were introduced in the 19th century had a major detrimental impact on the ecosystem. They prevented tree recruitment and destroyed the hardwood forest, thereby creating expansive open areas, increasing soil erosion and promoting the progressive ecological degradation, which culminated with the likely extinction of the Burrowing boa (*Bolyeria multocarinata*), the latest reptile to go extinct in Mauritius (Bullock 1986; Cheke & Hume 2008; North *et al*. 1994). By 1986, goats and rabbits had been eradicated (Merton 1987). Since then both the fauna and flora are recovering; reptile populations appear to have increased (Bullock 1986) and endemic plants are naturally regenerating (North *et al*. 1994). The extent of ground vegetation increased, albeit predominantly consisting of non-native species. Nevertheless, large unvegetated areas persist (Bullock 1986). In 2001 with the construction of a permanent field station, intensive restoration management was initiated to help recreate a native hardwood forest, control the exotic weeds, and to monitor the important reptile and seabird communities.

Every seven years since 1975 and biannually since the establishment of the field station, the population size of the reptile species has been surveyed. Some reptiles are believed to have reached their carrying capacity (North *et al*. 1994). Nevertheless, the Round Island reptiles remain vulnerable to stochastic and anthropogenic events like cyclones and tsunamis (North *et al*. 1994), or an accidental introduction of a predatory or competitive species, such as rats or house geckos (Bullock 1986). Insurance against such a disaster can be mitigated by establishing populations in alternative suitable recipient sites, such as other offshore islands free of potential predators. Translocation could help guarantee the persistence of the species, in addition to recreating lost interactions between the native fauna and flora (e.g. seed dispersal). However, translocations are only feasible with sufficient detailed studies, background research and knowledge of the biology and ecology of wild populations (Dodd & Seigel 1991; IUCN 1996).

In February 2007, 250 Telfair's skinks were relocated to Gunner's Quoin, where they once occurred (Arnold 2000; Cheke & Hume 2008), and 190 to Ile aux Aigrettes, which offers a suitable habitat and is predator-free (Cole *et al*. 2007). These initial translocations were the first of which will see all of the Round Island endemic reptiles being established elsewhere, in the near future. However, before future reptile translocations proceed, we need to investigate their diet and food and microhabitat requirements in order to help us identify the best recipient islands (Dodd & Seigel 1991).

The overall aim of this thesis is to provide the required scientific information to guide Round Island reptile conservation. In addition, data on the basic biology of the reptiles was compiled and the first study on the translocation of the Telfair's skinks to Ile aux Aigrettes was conducted.

Concept and outline of the thesis

This thesis has four general aims: (1) to estimate reptile population size and spatial variation, (2) to quantify the key feeding interactions and dietary demands of the Round Island reptiles, (3) to investigate the effect of Telfair's gut passage on seedling germination rate and survivorship, and (4) to study the translocation of Telfair's skink to Ile aux Aigrettes.

In order to address these issues, we employed several approaches including reptile censuses, telemetry and experimental techniques to improve our fundamental understanding of complex community interactions for conservation management. Our work presents findings on a range of scales: from detailed observational studies on species individuals, to an

extensive community-wide study of the entire reptile assemblage of Round island. Specifically, my thesis contains the following chapters:

Chapter 2 contains the first year long study on the population estimates and distributions of the entire reptile assemblage of Round Island, accounting for spatial and temporal effects. This 12 month long study monitored all the reptiles' populations on Round Island in all the seven habitats. We also investigated the effect of different parameters (season, month, habitat, temperature, rainfall and age) on population estimates and compared our estimate to those found by previous studies. In addition, we discuss the best methods for the future monitoring of the population size of Round Island reptiles. Accurately monitoring these reptile populations is vital to assess their status and risk of extinction, especially considering that most of the species are critically endangered.

Chapter 3 focuses on the variation in dietary preferences of the entire reptile assemblage of Round Island. We investigated diet content and temporal diet variation of the complete assemblage of the Round Island reptiles. Specifically, we examined the variation in the number of food items chosen, electivity indices and dietary niche overlap between the different reptiles. This was the first study to monitor the diets of all the Round Island reptile species at two different stages of development (adult and juvenile), for a period of 12 months and in all the 7 habitats of the island. This study has broadened our understanding of the feeding ecology of these species and provided essential information for the future consideration of reinstating populations on islands within the species' historic range

Chapter 4 documents the effects of Telfair's skink gut passage, on three endemics, four natives and two exotic fleshy fruit species from Round Island, on the germination rate and survivorship of seedlings. We also attempt to explain which factors were responsible for the effects found on the germination rate and survivorship of these species. This study is of significant interest, as the germination capacity of seeds after passing through the digestive tracts of lizard has received relatively little attention. Furthermore, Round Island's floral community is composed of both native and exotic species, the latter being a threat to the former. This study provides important insights on the effect gut passage have on seed germination and helps improve our understanding of how ecological restoration can benefit from reptile translocation.

Chapter 5 investigates the home range size, behaviour and movement of the Telfair's skinks (*Leiolopisma telfairii*) on Round Island and Ile aux Aigrettes. To understand the homing capacity of the Telfair's skink better, we conducted a relocation experiment on 21 Telfair's skinks on Round Island. This study provides essential information for ongoing and

future translocation efforts. Furthermore, incorporating measures of animal behaviour into evaluations of restoration success provides critical information that is not apparent from animal species composition and richness estimates. This study provides information at an individual level, thus allowing for a better understanding of the home range size, movement and behaviour which is often ignored in population level studies.

Each chapter is written as independent manuscripts for publication. Therefore, there is inevitably some overlap. In particular, there is an obvious repetitiveness in the study site sections of the papers.

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CHAPTER 2

A new method to estimate reptile population size in ecologically sensitive areas: reptile species of Round Island, Mauritius as an example

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A new method to estimate reptile population size in ecologically sensitive areas: Round Island (Mauritius) as an example

Abstract

Accurate population size estimates of endangered species are crucial for their effective conservation. Traditional methods to estimate endangered reptile populations are often either lacking accuracy (e.g. belt transect methods) or are due to their destructive nature not applicable in ecologically sensitive areas (large-scale total removal plots). Furthermore, population size is often estimated from data obtained by sampling designs not adequately accounting for spatial and temporal variability. Here, we estimated the population size of all 7 endangered reptile species in all habitats over 12 month of Round Island, Mauritius, using a new method. This method combines large-scale belt transects with a small-scale, modified version of Rodda's total removal quadrat method to maximise accuracy and minimise impacts on the ecosystem. Estimates differed with parameters such as temperature, rainfall, reptile age, season, month and habitat, thus emphasising the importance to incorporate these parameters variability in future studies. Our estimates differed considerably to past studies, which in general were spatially and temporally limited. From conservation perspective, it is important to accurately assess population size for future protection measures. We conclude that the method proposed here is useful to estimate population size for endangered reptiles' species in ecologically sensitive areas. The Round Island reptile assemblage is healthy in term of population size and no species appeared to be in imminent danger of extinction

Introduction

The extinction of species in the tropics is proceeding rapidly, primarily because of the destruction and the fragmentation of habitats, and introduction of invasive alien species (Reaser *et al*. 2007). Consequently, improving methods to conserve threatened species are crucial (Fischer & Lindenmayer 2000; Gipps 1991). Prior to adopting a conservation strategy, detailed studies of the biology and ecology of wild populations are required (IUCN 1996). The population size is of vital significance (Buckland *et al*. 1993; Krebs 1985). However, determining population size can be problematic (Heckel & Roughgarden 1979; Rodda *et al*. 2001b).

Population size estimates are often not representative of the true population because they were obtained from study areas chosen for the high abundance of the target species, instead of being representative of the whole habitat range of the population (Rodda *et al*. 2001b). In addition, many studies fail to account for temporal variations in population size (Beissinger & McCullough 2002; Pianka 1973). Estimates from unsystematic surveys are often inaccurate and thereby may present a misleading status of the species (Rodda *et al*. 2001b). Reliable field data are essential to establish baseline information on abundance and to clarify the actuality, extent and pattern of a population (Diaz *et al*. 2006). Hence, Improving estimators or methods to most accurately determine the population size is imperative (Diaz *et al*. 2006).

Reptiles represent approximately 30% of all terrestrial vertebrates and generally attain higher densities than birds and mammals (Fa & Purvis 1997; Uetz 2000; Welty & Baptista 1988) though they are so abundant estimating population size is problematic. Lizards' ectothermic nature and insectivorous diet enables them to reach high densities in low productive ecosystems because they can successfully exploit a large prey base that most endothermic predators cannot energetically afford to feed on (Regal 1983).

Islands often harbour a plethora of unique fauna and flora (Cheke & Hume 2008). Disharmony in these ecosystems is a common consequence of long distance isolation from nearby large land masses (Cheke & Hume 2008). The adaptive radiation of the founding reptile taxa on Mauritius led to it having possibly one of the richest endemic reptile assemblages for an oceanic island of its size (Cheke & Hume 2008). The terrestrial reptiles were a major component of the Mauritian ecosystems and were probably the most abundant vertebrate group (Cheke & Hume 2008). The absence of a large mammalian taxa, enabled the reptiles to attain high population densities as they had no major predators (Cheke & Hume 2008). Round Island is one of these offshore islands; it is the only island to have retain 70 % of its original reptile fauna, due to a lack of introduced predatory mammals and reptiles (Arnold 2000).

Former studies estimating population sizes of reptiles on Round Island were confined to specific habitats (Dulloo *et al*. 1999; Vinson 1975; Vinson & Vinson 1969) and often lacked of scientific rigour (Jones & Hartley 1995; Vinson 1975; Vinson & Vinson 1969) and were snapshot recordings of a maximum of a few weeks (Cole 2005; Ingversen 2004; Korsos & Trocsanyi 2001; Nichols & Freeman 2004; Pernetta 2004). Data for entire assemblages of reptiles are rare (Rodda *et al*. 2001a). Hence this study is of significant value not only to determine the status of the Round Island reptiles, but to provide information on how reptile

dominated areas exist. Accurately monitoring these populations is vital to assess their status and risk of extinction, especially considering that most of the species are critically endangered. Conservation measures are often applied to a species following a drop in the population size, initial inaccurate estimates might have dramatic consequences on the fate of these species. Furthermore, changes in the abundance of the reptile species should provide a measure of the overall effect of the long-term restoration work on Round Island.

The aim of this study was twofold: first, to provide accurate population estimates of the entire reptile assemblage of Round Island by sampling each habitat during a whole year; second, to develop and test a new method to most accurately estimate endangered reptile populations with a minimum of destructive sampling. In addition, we investigated the effect of different parameters (season, month, habitat, temperature, rainfall and age) on population estimates and compared our estimates to those found by previous studies.

Materials and methods

Study species

The Round Island herpetofauna is outstanding (North *et al*. 1994): eight species are recorded, of which seven are Mascarene endemics and four are now confined to Round Island (North *et al*. 1994; Vinson 1975). However, within the last few decades, the adverse impact of rabbits and goats has caused the probable extinction of the Burrowing boa, *Bolyeria multocarinata,* last seen in 1975 (North *et al*. 1994).

The Round island herpetofauna is composed of 3 skinks: Telfair's skink (*Leiolopisma telfairii)*, Bojer's skink (*Gongylomorphus bojeri*) and Bouton's skink (*Cryptoblepharus boutonii*), 3 geckos: Guenther's gecko (*Phelsuma guentheri*), the Ornate day gecko (*Phelsuma ornata*) and Durrells' night gecko (*Nactus durrelli*) and 2 snakes (boa): the Keel-scaled boa (*Casarea dussumerii*) and the Burrowing boa (*Bolyeria multocarinata*).

Study sites

The study was conducted on Round Island. Round Island (57°47□03□E, 19°54□03□S) is a basaltic volcanic cone, located 22.4 km off the north coast of Mauritius (Merton *et al*. 1989). Mauritius (57°33□02□E, 20°17□03□S) is roughly 830 km east of central Madagascar in the Indian Ocean (Fig.1) and is part of the Mascarene archipelago, together with the neighbouring islands of Réunion and Rodrigues.

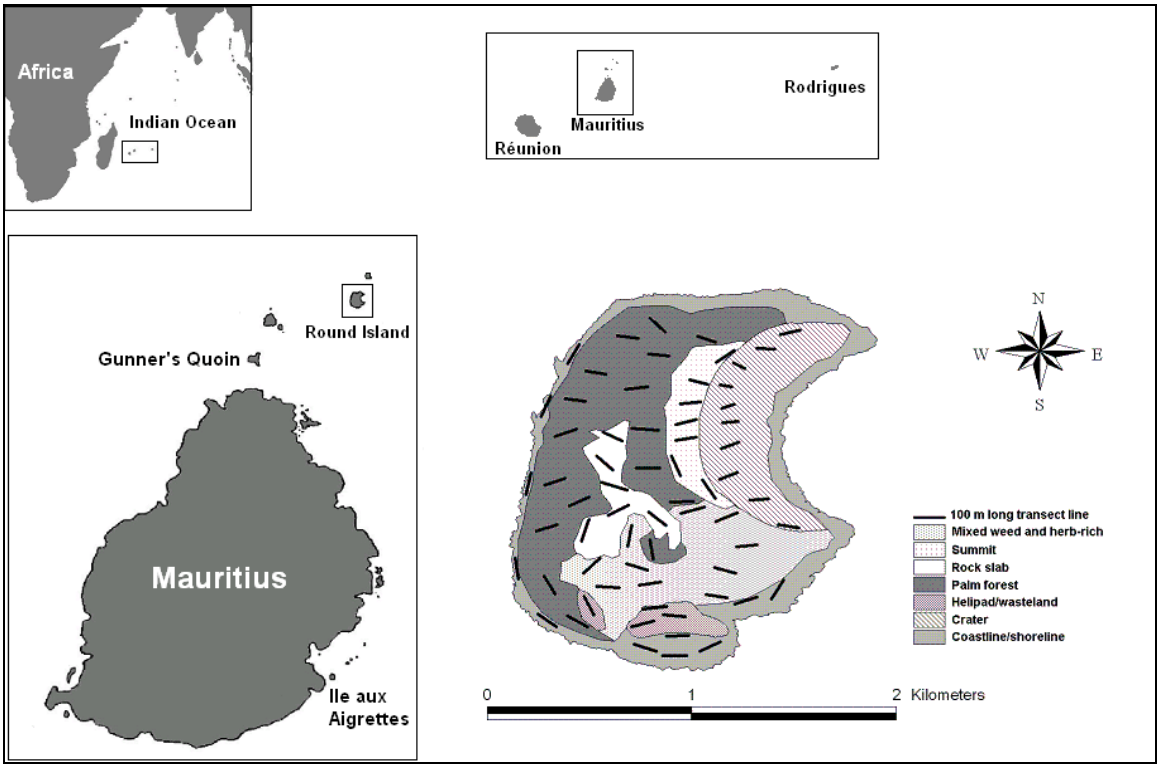

Figure 1 Location of Mauritius and Round Island, showing the 7 habitats and the location of the 65 transects.

Round Island covers an area of 215 ha and rises to 280 m above sea level (Johansson 2003). The island was divided into seven distinct habitat types according to vegetation and substrate (modified and updated from (Johansson 2003)) (Fig. 1 & Table 1).

Table 1. Surface area in hectares of the seven habitats on Round Island and the number of belt transect line set up in each habitat.

Habitat	Surface area /ha	Number of transect lines
Palm forest	65.94	17 transects
Coastline/shoreline	40.36	11 transects
Mixed weed and herb-rich	36.68	10 transects
Crater	34.60	10 transects
Summit	15.85	7 transects
Rock slab	13.27	6 transects
Helipad/wasteland	8.30	4 transects

New method to estimate reptile population size

To accurately estimate the reptile populations with a minimum of destructive sampling, we applied a new method by combining two commonly applied approaches: total removal plots and belt transects (Rodda *et al*. 2001a; Sutherland 2006). Rodda and colleagues (2001a) stated that there is no reliable technique to estimate population densities other than the total removal method, which will provide the most accurate estimation of small lizard densities. This method is highly sensitive in detecting cryptic or elusive species that would otherwise be

undetected. Since Round Island is a closed nature reserve (Merton *et al*. 1989), extensive destruction of habitats with large removal plots over a period of 1 year was not feasible. Belt transects on the other hand have known limitations, such as under estimating cryptic species (Sutherland 2006). As a potential solution to this dilemma, we tested a new method by using small scale removal plots to generate a correction factor for belt transect estimates.

To establish the small scale removal plots unclimbable greased lizard-proof 0.5 m high, 1 m^2 aluminium quadrats were buried 0.1 m into the ground near the transects (see Rodda (2001a) for further details). First, the designated quadrat location was surveyed for reptiles, and then the reptile-proof quadrat described above inserted. Subsequently, all the vegetation within the quadrat was removed and examined for cryptic or elusive reptiles. This provided a precise measure of abundance and was used to generate a correction factor to determine the absolute estimate. Five total removal quadrats were conducted monthly for each habitat and time period (from 6:00 to 10:00, 10:00 to 14:00, 14:00 to 18:00 and 18:00 to 22:00). The correction factor was calculated by dividing the number of observed reptiles after destruction, by the number of observed reptiles before destruction. To correct the estimates from the belt transects, the number of reptiles found in each habitat were multiplied by the respective correction factors.

The belt transects used in this study were 4 m wide, as recommended for high density reptile population (Sutherland 2006). Since the seven habitats vary in size (Table 1), stratified sampling was done. A total of 65 100 m long belt transects were randomly distributed using an extension of Arcview 3.2 (the Random point generator) and permanently established across the seven habitats, based on the surface area of each habitat (Fig. 1 & Table 1). In our case, the criteria for the positioning of the transects line were: each transect was placed at fix distance from each other based on the size of the habitat and the orientation was set to go up the slope of the island.

Each belt transect was surveyed monthly during an entire year (July 2006 to June 2007). Within a habitat, transects were randomly assigned to one of the following time periods to account for temporal differences in reptile counts (from 6:00 to 10:00, 10:00 to 14:00, 14:00 to 18:00 and 18:00 to 22:00). All reptiles observed within the belt transects were recorded, and classified as either adult or juvenile based on their Svl (Snout to vent length). If the Svl of the individual < 40 mm, they were classified as juvenile for the Bojer's skink, Bouton's skink, Ornate day gecko and Durrells' night gecko and if it was < 100 mm as juvenile for the Guenther's gecko and Telfair's skink. The difference between juvenile and adult for the Keel-scaled boa was based on their colouration if they were orange coloured;

they were juvenile, if blue-black then they were adult. Since reptiles were active during different time periods during the day and the seasons, each reptile population size was estimated from transect walks at the respective peak activity. We will refer to peak activity as "activity pattern" hereafter. Using our one-year dataset, we determined when each species was active and used this information to generate our estimates.

Rainfall, temperature and season

Knowing that rainfall, temperature and the season affects reptile activity. Rainfall was recorded every morning for the previous 24 hours using a standard rain gauge. At the end of the month, the rainfall data was summed to obtain the rainfall per month. Based on rainfall data, we classified June to November as the dry season, and December to May as the wet season. Temperature was recorded at the start and end of each transect walk. The highest and lowest temperatures were determined daily, and the mean daily temperature calculated.

Statistical analyses

Data were analysed by fitting generalised linear models (GLMs), using the software package R.2.7.0 (R Development Core Team 2008). A GLM (using quasi-Poisson error distribution) with species, temperature (lower and maximum mean), rainfall, habitat, month, season and age as explanatory variables was fitted to analyse variation in population estimate size. To account for statistical overdispersion, mean deviance changes were compared with *F*-tests (Crawley 2005).

Since we were particularly interested in differential effects of the explanatory variables of the different reptile species at different life-history stages on the population size estimate, separate GLMs for each reptile species and life-history stage (adult and juvenile) were fitted. To avoid overfitting, two models instead of one had to be fitted: in a first model, the effects of the explanatory variables temperature (lower and maximum mean) and rainfall on population size was tested. In a second model, habitat, season and month were the explanatory variables.

Results

Species distribution and range on Round Island

Only the Telfair's and Bojer's skink used all the habitats of Round Island (Fig. 2). The most restricted reptile was the Bouton's skink which occurred only on the coastline. The other reptiles used most habitats (Fig. 2).

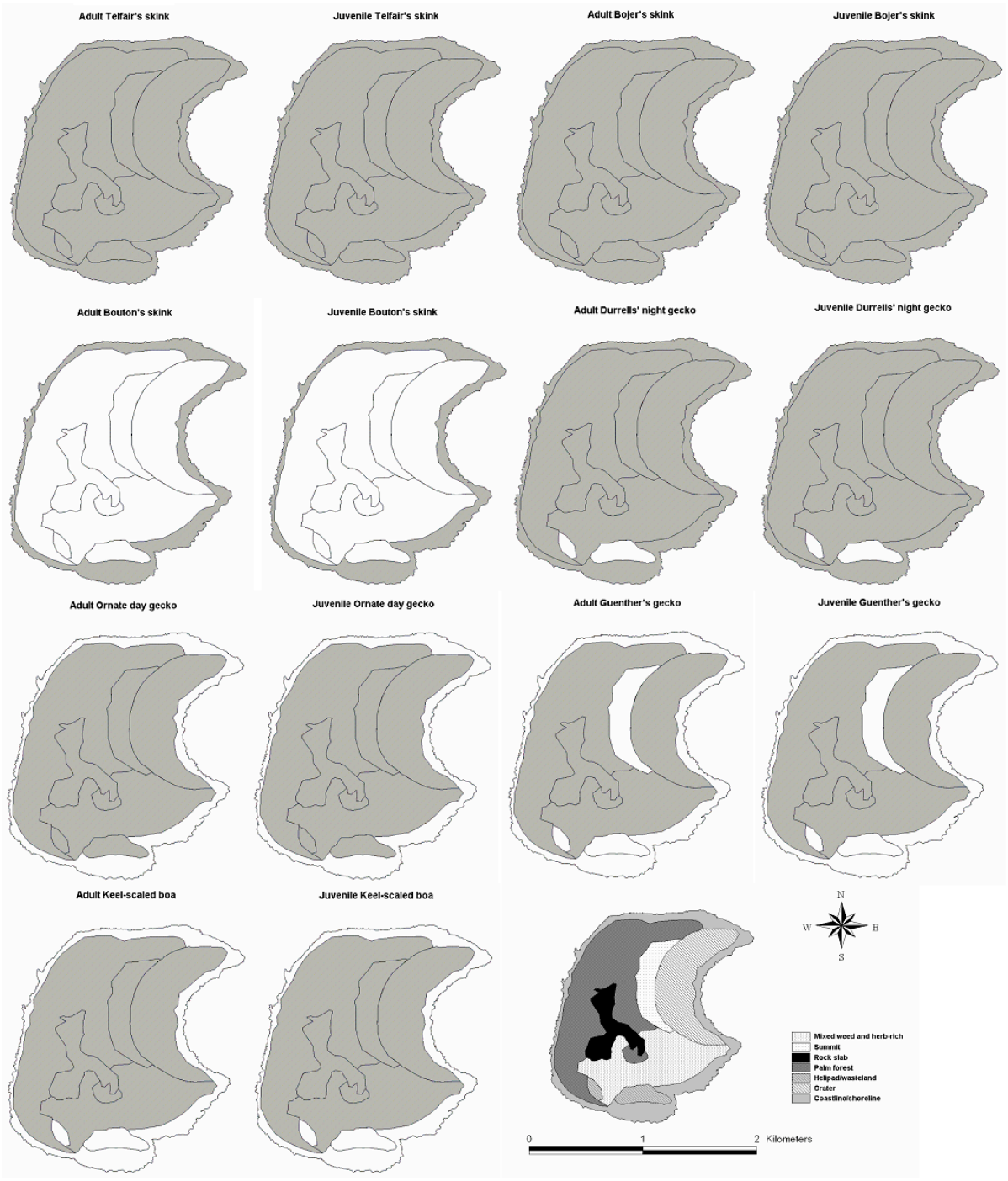

Figure 2. Distribution maps for the adult and juvenile reptile species of Round Island. Grey shading indicates the occupancy of the habitat by a species, while white highlights its absence. The seven different habitats are illustrated in the bottom right map.

Population estimates of the Round Island reptile assemblage

Using our new method combining belt transect and a total removal quadrat method, we have produced the first population size estimates of the entire assemblage of Round Island reptiles from data collected in all the 7 habitats of the island over a period of 12 months (Table 2 & 3).

Table 2. Uncorrected (belt transect data only) and corrected (belt transect and correction factor obtained from total removal quadrat sampling) population estimates of the entire assemblage of Round Island reptiles for a period of 12 months and over all seven habitat types. Means with standard deviations (in brackets) are given

Reptile species	Population estimate	
	Uncorrected	Corrected
Telfair's skink Adult	16,658 (±4,077)	21,468 (±12,321)
Telfair's skink Juvenile	3,709(±774)	4,606 (±1,734)
Bojer's skink Adult	43,666 (±18,748)	62,255 (±32,794)
Bojer's skink Juvenile	3,511 (±2,393)	5,901 (±6,082)
Bouton's skink Adult	450 (±257)	450 (±257)
Bouton's skink Juvenile	124 (±121)	124 (±121)
Ornate day gecko Adult	5,485 (±1,045)	8,823 (±2,931)
Ornate day gecko Juvenile	1,599 (±530)	2,496 (±1,559)
Guenther's gecko Adult	1,925 (±503)	2,246 (±761)
Guenther's gecko Juvenile	1,269 (±561)	1,590 (±763)
Durrells' night gecko Adult	3,319 (±1,332)	4,968 (±2,578)
Durrells' night gecko Juvenile	783 (±503)	876 (±581)
Keel-scaled Boa Adult	574 (±202)	813 (±323)
Keel-scaled Boa Juvenile	350 (±208)	359 (±199)

When population estimates were corrected, differences for the estimates of most species were apparent, particularly for abundant species. Only the estimates of the Bouton's skink remained unchanged (Table 2).

Effects of temperature, rainfall, age, season, month and habitat on population estimates of the Round Island reptile assemblage

Using the pooled data of all reptile species together, mean daily maximum temperature per month ($F_{1,1174}$= 2.05, P<0.0001) was significantly positively correlated with population estimate; when testing species separately, positive correlations were found for some species like the Bojer's skink and Ornate day gecko, but also negative correlations were found for the Telfair's skink and Guenther's gecko. Mean monthly precipitation showed a trend for a negative correlation with population estimate of the pooled data of all species ($F_{1,1171}$= 2.77, P=0.096). Mean population estimate for the pooled species differed among habitats

($F_{6,1169}$= 24.45, P<0.0001) and months ($F_{10,1158}$= 2.66, P=0.003), but not seasonally ($F_{2,1168}$= 0.99, P=0.319). Categorising seasons in Mauritius is relatively arbitrary as the island experiences irregular weather patterns, thus seasons are loose and can change yearly. Furthermore, mean population estimate of the pooled species differed for adults and juveniles ($F_{1,1174}$= 9.48, P<0.0001).

Further investigation at the species (7 species) and age (adult and juvenile) levels, found that most population estimates were affected by high temperature, with the exception of the adult Bouton's skink and some of the juvenile species, namely the Bojer's skink, Bouton's skink, Durrells' night gecko, and Keel-scaled boa (Table 4). However, low temperature affected the population estimates for the Ornate day gecko juvenile. Rainfall influenced only the Telfair's skink adult estimates (Table 4).

Table 4 Summary of the GLMs used to investigate if low and high temperatures and rainfall affected the reptile population estimates on Round Island. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold and Leitel= *Leiolopisma telfairii,* Gonboj= *Gongylomorphus bojeri,* Crybou= *Cryptoblepharus boutonii,* Pheorn= *Phelsuma ornata,* Phegue= *Phelsuma guentheri*, Nacdur= *Nactus durrelli, Casdus= Casarea dussumerii,* Ad= Adult and Juv= Juvenile. The highest and lowest temperatures were determined daily, and the mean daily and monthly temperature calculated.

Species	Low temperature			High Temperature			Rainfall		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Leitel Ad	1,82	3.82	0.054	1,81	34.37	**<0.0001**	1,80	7.39	**0.008**
Leitel Juv	1,82	1.18	0.280	1,81	18.49	**<0.0001**	1,80	0.23	0.633
Gonboj Ad	1,82	0.53	0.470	1,81	10.90	**0.002**	1,80	1.26	0.266
Gonboj Juv	1,82	0.69	0.410	1,81	0.01	0.939	1,80	2.20	0.142
Crybou Ad	1,82	0.02	0.877	1,81	0.19	0.662	1,80	0.42	0.520
Crybou Juv	1,82	0.03	0.862	1,81	0.07	0.800	1,80	0.22	0.637
Pheorn Ad	1,82	3.58	0.062	1,81	37.77	**<0.0001**	1,80	0.37	0.544
Pheorn Juv	1,82	9.79	**0.002**	1,81	33.69	**<0.0001**	1,80	0.38	0.542
Phegue Ad	1,82	0.33	0.566	1,81	30.98	**<0.0001**	1,80	0.21	0.650
Phegue Juv	1,82	2.72	0.103	1,81	5.71	**0.019**	1,80	2.83	0.096
Nacdur Ad	1,82	0.01	0.913	1,81	7.06	**0.009**	1,80	1.74	0.190
Nacdur Juv	1,82	2.65	0.108	1,81	3.61	0.061	1,80	0.183	0.670
Casdus Ad	1,82	1.44	0.233	1,81	5.93	**0.017**	1,80	0.40	0.529
Casdus Juv	1,82	0.047	0.829	1,81	2.18	0.144	1,80	0.11	0.739

The habitat type affected the population estimates for all reptiles (Table 5, Fig. 3). However, only species highly bounded to their habitat were affected seasonally; namely the Bouton's skink, Durrells' night gecko and the Guenther's gecko. Only the Bouton's skink, Bojer's skink and the Guenther's gecko population estimates differed monthly (Table 3 & 5, Fig. 3, Appendix I)

Table 3. Corrected (belt transect and correction factor obtained from total removal quadrat sampling) monthly population density estimates of the entire assemblages of Round Island reptiles for a period of 12 months.

Reptile species	January	February	March	April	May	June	July	August	September	October	November	December	Population estimate
Telfair's skink Adult	18382	55800	18246	19212	18103	12071	9808	25473	13947	24743	29480	12349	21468
Telfair's skink Juvenile	3671	6120	6362	3351	2831	3445	3167	4265	5314	4473	3553	8720	4606
Bojer's skink Adult	64466	89358	47322	34752	38966	27685	21061	48974	139117	121530	72585	41238	62255
Bojer's skink Juvenile	1955	18061	1640	1270	510	409	4408	7297	17496	7446	6297	4018	5901
Bouton's skink Adult	186	186	558	558	372	372	744	372	186	931	744	186	450
Bouton's skink Juvenile	0	186	186	0	186	186	186	186	372	0	0	0	124
Ornate day gecko Adult	12951	11992	6943	7216	8683	5916	4867	7858	14429	9938	7188	7892	8823
Ornate day gecko Juvenile	2561	2245	2720	6451	872	1506	4302	2673	1137	1066	2287	2127	2496
Guenther's gecko Adult	2718	1954	2386	2386	1837	1736	1404	1340	2169	2386	2386	4250	2246
Guenther's gecko Juvenile	855	881	3052	2286	2477	1736	1431	982	1099	1008	2322	946	1590
Durrells' night gecko Adult	10880	4048	4655	8615	6156	5580	2260	2386	4222	2674	3485	4655	4968
Durrells' night gecko Juvenile	1558	550	550	728	0	396	0	1415	1495	1404	1404	1008	876
Keel-scaled Boa Adult	1028	946	920	808	583	616	220	621	726	1280	1388	616	813
Keel-scaled Boa Juvenile	365	675	478	364	414	176	110	334	110	220	730	333	369

Table 5. Summary of the GLMs used to investigate if habitat, season and month affected the reptile population estimates on Round Island. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold and Leitel = *Leiolopisma telfairii,* Gonboj = *Gongylomorphus bojeri,* Crybou = *Cryptoblepharus boutonii,* Pheorn = *Phelsuma ornata,* Phegue = *Phelsuma guentheri*, Nacdur = *Nactus durrelli, Casdus* = *Casarea dussumerii*. Seasons were classified as the dry season from June to November and the wet season from December to May.

Species	Habitat			Seasons			Months		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Leitel	6,161	28.46	**<0.0001**	1,160	0.90	0.344	11,150	1.92	0.053
Gonboj	6,161	12.34	**<0.0001**	1,160	2.03	0.133	11,150	2.23	**0.024**
Crybou	6,161	111.17	**<0.0001**	1,160	7.27	**0.008**	11,150	2.41	**0.014**
Pheorn	6,161	70.06	**<0.0001**	1,160	0.01	0.995	11,150	0.82	0.614
Phegue	6,161	49.49	**<0.0001**	1,160	18.0	**<0.0001**	11,150	2.80	**0.005**
Nacdur	6,161	9.18	**<0.0001**	1,160	5.7	**0.019**	11,150	0.82	0.607
Casdus	6,161	24.59	**<0.0001**	1,160	8.07	**0.006**	11,150	0.68	0.743

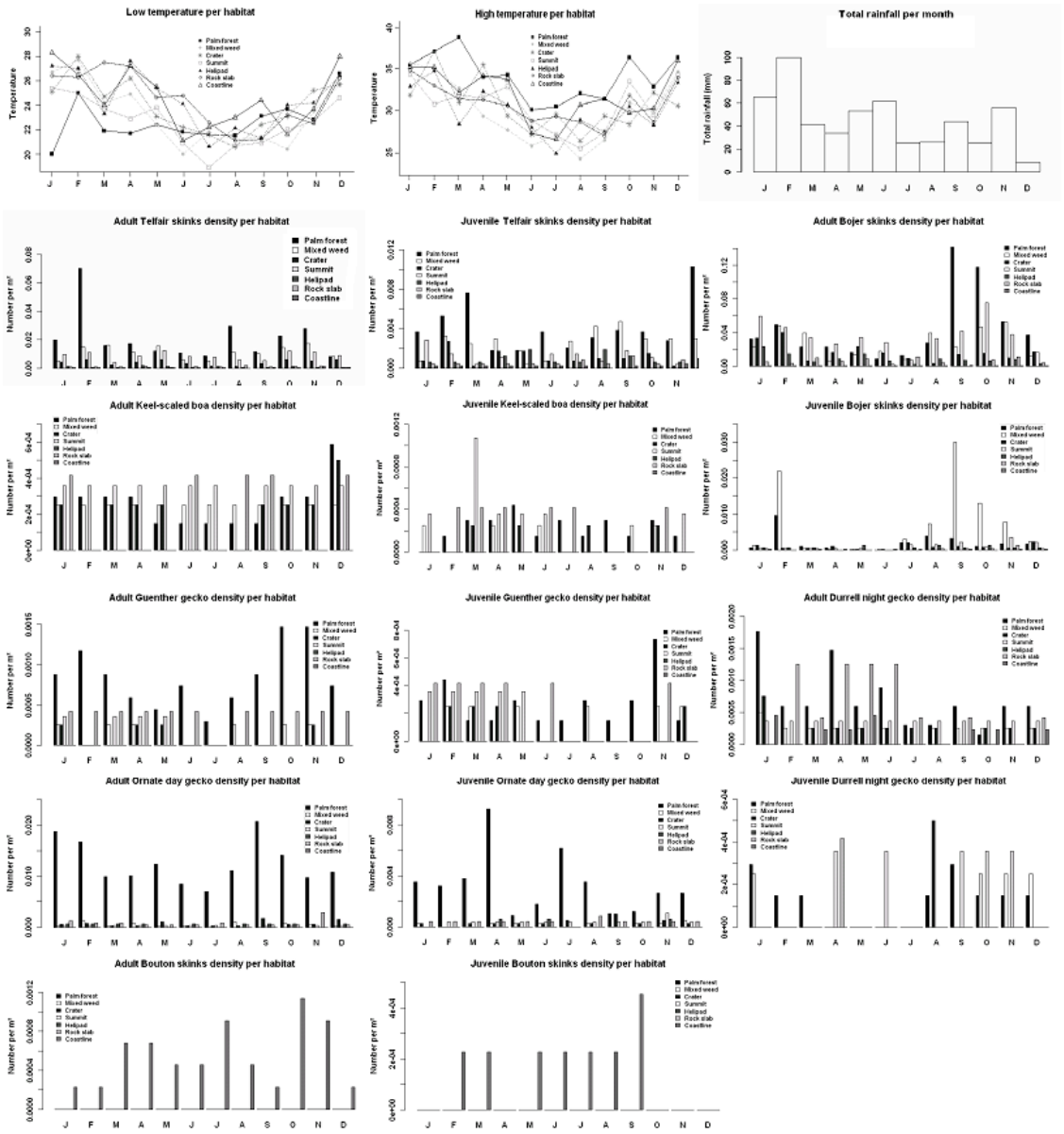

Figure 3. Variation in rainfall (not shown to habitat scale), high and low temperatures, population densities (per m^2) of the seven reptile species within the seven Round Island habitats over one year.

Discussion

Population estimate, species distribution and range of the Round Island reptile assemblage

The present study provides the comprehensive and accurate population estimates of all the 7 species of the reptile assemblage of Round Island to date, by accounting for (1) the cryptic nature of reptiles by conducting destructive quadrats and generating a correction factor (2) temporal variation, (3) spatial variation, (4) reptile activity patterns, and (5) abiotic factors, such as temperature and rainfall.

Only the Telfair's and Bojer's skink used all the habitats of Round Island, these 2 species occur sympatrically. This is due to their omnivore's nature (see chapter 3) and their great adaptability to diverse habitats (Jones 1993). The most restricted reptile was the Bouton's skink which occurs only on the coastline. This is due to their adaptability to predate from rock pools and the splash zone and heir smaller size enabling them to hide in small cracks. The other reptiles used most habitats at the exception of some (see Fig. 2 & 3), Ornate day gecko on the Coastline; the Keel-scaled boa on the Coastline and Helipad; and the Guenther's gecko on the Summit, Helipad and Coastline. The Durrells' night gecko did not occur on the Helipad, as they need sandy rocky structures with cracks (Cole 2005), which are not present on this habitat. The Guenther's gecko did not occur on the Summit, Helipad and Coastline and Ornate day gecko on the Coastline as they need clusters of *Latania* palms and *Pandanus* trees (Bullock 1986), which are absent or too few in these habitats. The Keel-scaled boa did not occur on the Coastline and Helipad as they lack shelters for the boas, which need *Latania* palms and *Pandanus* trees or rocky structures (Bullock 1986).

Our results confirm what Rodda (2001a) found, without correcting population estimates, they can be underestimated. The total removal quadrat used to generate a correction factor, refined our estimates. It is noticeable that the corrected estimate of the Bouton's skink did not differ from uncorrected estimate and the standard deviation for the juvenile estimate in this species was exceptionally high. This is due to the failure to locate any juvenile Bouton's skinks in five months of the year (see Table 2). Another possible explanation is that the Bouton's skink occurs only on the coastline habitat (see Fig.2.) which is mainly barred rock and little vegetation. Bouton's skink hides in rock cracks, as we did not break rocks, the total removal quadrat did not correct for this species population estimate.

According to our population estimates, most reptile populations on Round Island seem large enough not to be immediately threatened by adverse genetic and demographic effects.

The estimated population size of the Bouton's skink (574 individuals), however, may be considered as critical. According to Simberloff (1988) the rule of thumb of a minimum viable population for reptiles is around 50 individuals to prevent inbreeding depression and around 500 individuals to maintain a growing population, robust against erosion of genetic variability. No species appears in immediate danger of extinction, as all have sustainable populations (Traill *et al*. 2007). However, since the populations of mostly endemic reptile species of Round Island will always be threatened by stochastic events and natural catastrophes, translocation of parts of them is crucial for the long-term conservation of these species. Fischer and Lindenmayer (2000) found that translocation success increased to more than 70 % if more than 100 individuals were released, but decreased to 36 % if more than 200 individuals were released. Our population size estimates suggest that the populations of all reptile species on Round Island are large enough to undergo translocation, without leaving the source population non-viable and vulnerable to adverse genetic effects (Simberloff 1988). Nevertheless, future translocations of Bouton's skinks should be carefully planned, with numbers of skinks translocated optimally not exceeding around 100 individuals in a first translocation project.

Despite claims that the island has reached its carrying capacity in terms of reptiles, we believe that this is not the case as more affable microhabitat will be made available to the reptiles and their number is bound to increase in progress with the continuing restoration work.

Since there are hugely dissimilar estimates for the population of some reptiles, this is a source of concern as other reptile populations in Mauritius are less well studied and considered at greater risk to extinction as they occur in more fragile environments. A re-evaluation of other Mauritian reptile populations is strongly recommended.

Effects of temperature, rainfall, age, season, month and habitat on population estimates of the Round Island reptile assemblage

Many factors, such as temperature (Krebs 1985; Sutherland 2006), vegetation type (Buckland *et al*. 1993; Rodda *et al*. 2001b) and season and months (Krebs 1985; Rodda *et al*. 2001a), influence activity patterns and distribution of these ectothermic organisms. Our results confirmed a positive relationship between reptile sightings and high temperature. This positive relationship was also found on lizard and snake populations by (Buckley *et al*. 2008; Luiselli & Akani 2002; Shine & Madsen 1996). However, there was an inverse relationship with rainfall; sightings decreased with increasing rainfall, especially for the Telfair's skink.

This inverse relationship, was also found in species of dragon lizards and snakes by (Dickman *et al*. 1999; Morton & James 1988; Reagan 1986). We also confirmed that reptile estimates varied according to the habitat and months, as found elsewhere by (Buckland *et al*. 1993; Buckley *et al*. 2008; Krebs 1985). These influential factors are thus important, and need to be taken into account when estimating population sizes.

Comparison of Population estimates of the Round Island reptile assemblage

Estimation of Round Island's reptile populations started in 1969 with the first estimation by Vinson. Despite his estimation lacking scientific rigour, it was important to assess Round Island's reptile populations (Jones & Hartley 1995). In 1975, Bullock and North produced the first scientific population estimates from direct counts in fixed areas for the predominantly terrestrial reptiles and in trees for the arboreal *Phelsuma*'s geckos (North & Bullock 1986). They repeat this survey every 7 years (5 surveys to date). Since then others have studied all the 7 species (Dulloo *et al*. 1999; Vinson 1975; Vinson & Vinson 1969) or some of the reptiles (Cole 2005; Ingversen 2004; Korsos & Trocsanyi 2001; Nichols & Freeman 2004; Pernetta 2004).

When we compared our data to previous work, the first striking difference is that none had studied the whole assemblage of reptiles (see Table 6). Furthermore, none distinguished between adult and the juvenile reptiles. They all estimated whole population size. Most were short term and none as extensive as ours (see Table 6). Although, North and Bullock have conducted 5 surveys to date, every 7 years, there is significant variability between estimates (Dulloo *et al*. 1999). There was significant variation in the estimation of the most common reptile, the Telfair's skink between studies. Our results were comparable to those of Pernetta *et al*. (2004) and Korsos & Trocsanyi (2001), but differed hugely to Dulloo *et al*. (1999) 100,830 estimate. Our estimate for the Guenther's gecko and Bojer's skink also differs widely to that of Dulloo *et al*. (1999) who surveyed only five of the seven habitats for a period of two weeks (see Table 6). One reason for this difference in estimates may be the extrapolation as before the study by Johansson (2003), areas on Round Island were not properly estimated. Therefore extrapolating is likely to be more inaccurate. Another reason might be the high monthly variation in population estimate (see Table 3) which could explain why there is such large variation in estimates between studies. For example, if boa population were done in July, this would produce a low estimate, whereas in November, a high estimate.

Table 6. Summary of all the studies conducted to estimate the Round Island reptile populations: the population estimates, the method used, year and month done, areas studied and length of time of the study. For the area studied, Ps = Palm forest, Mw = Mixed-weed, Cr = Crater, Su = Summit, He = Helipad, Ro = Rock slab and Co = Coastline.

Studies	Vinson & Vinson	Vinson	Bullock	North et al.	Arnold & Jones	Dulloo et al.	Korsos & Trocsanyi	Permetta	Nichols & Freeman	Zuël et al.
Year	1969	1975	1986	1994	1994	1999	2000	2004	2004	2006-2007
Month	August	September	July	July	July	July	June	March-May	November-March	All months
Time of study	1 week	1 week	2 weeks	3 weeks	1 week	2 weeks	1 month	3 months	5 months	1 year
Area studied	Ps & Su	Ps & Su	Ps, Mw, Su,He, Ro	Ps, Mw, Su,He, Ro	Ps, Mw, Su,He, Ro	Ps, Mw, Su,He, Ro	Ps	Ps, Mw, Su,He	Ps, Mw, Su,He	All
Method	Direct counts	Direct counts	Transects	Direct counts	Transects	Mark-recapture	Total removal	Mark-recapture	Molecular markers	Transects & total removal
Telfair's skink Adult	-	4000-5000	518-851	465-933	-	100830	33300	26400	-	21468
Telfair's skink Juvenile	-	-	-	-	-	-	-	-	-	4606
Bojer's skink Adult	-	12000-15000	738-1613	883-1363	-	>150000	-	-	870-6000	62255
Bojer's skink Juvenile	-	-	-	-	-	-	-	-	-	5901
Bouton's skink Adult	-	100	-	-	-	-	-	-	-	450
Bouton's skink Juvenile	-	-	-	-	-	-	-	-	-	124
Ornate day gecko Adult	-	-	938-1789	562-1173	-	-	-	-	-	8823
Ornate day gecko Juvenile	-	-	-	-	-	-	-	-	-	2496
Guenther's gecko Adult	150-300	1500-1800	181-553	41-76	-	3426	4430	-	-	2246
Guenther's gecko Juvenile	-	-	-	-	-	-	-	-	-	1590
Durrells' night gecko Adult	-	4000-5000	-	10-210	10000	-	-	-	-	4968
Durrells' night gecko Juvenile	-	-	-	-	-	-	-	-	-	876
Keel-scaled Boa Adult	-	-	-	8-37	-	-	-	-	-	813
Keel-scaled Boa Juvenile	-	-	-	-	-	-	-	-	-	369

When we compared the three studies done by Bullock and his team (Bullock 1986; Dulloo *et al*. 1999; North *et al*. 1994). The three estimates for the different species are very contrasting (see Table 6); doing it every seven years is unlikely to be very accurate or reliable. These studies are unlikely to detect any changes in the population size and could hide a problem if some factors (like disease or introduced predator/competitor) are affecting population size. Their estimates can be dangerous in terms of conservation, this is why we claim that reptiles estimate in Mauritius should be re-evaluated.

The analyses of this study suggest that the huge variation between our estimates and most of the previous studies (Dulloo *et al*. 1999; Nichols & Freeman 2004; North & Bullock 1986; North *et al*. 1994; Vinson 1975) primarily caused by the a lack of robustness of previous sampling protocols due to a lack of incorporating for (1) the cryptic nature of reptiles by conducting destructive quadrats and generating a correction factor (2) temporal variation, (3) spatial variation, (4) reptile activity patterns, and (5) abiotic factors. Our new method demonstrate that temporal and spatial variation can significantly affect the population estimates as these fluctuated with month and habitat in our study. Another important factor which we considered when calculating the population size was the reptiles' activity patterns (Bullock 1986; Krebs 1985). If a species was not active at a certain time period, incorporating these inactive time periods to calculate the population estimates would have resulted in an underestimation of the population size. Previous studies (Bullock 1986; Nichols & Freeman 2004; Vinson 1975) estimating Round Island reptile populations did not account for the animal's activity patterns.

We propose that the combination of belt transects and destructive sampling are an ideal method to estimate reptile populations on Round Island. This method is particularly appropriate for reptile population estimates in "sensitive" ecosystems, were large destructive quadrats are not feasible, such as protected areas, or when threatened species population are to be estimated. Before obtaining absolute population estimates of reptiles, it is clear that a detailed knowledge of their biology is essential, as this affects the choice of the sampling method as well as the timing and location (Burn & Underwood 2001; Sutherland 2006). Another important aspect is the general spatial distribution of the species; in particular, knowledge of ranges, especially for species which exhibit territorial behaviour, as the size and placement of quadrats or transects will influence an estimate (Krebs 1985; Sutherland 2006). That is why we sampled all the habitats and spaced the transect lines evenly. If we want to compare abundance estimates between species then the same sampling methods should be used (Sutherland 2006). Recording weather variables must also be carried throughout a

monitoring program as reptile activity is highly correlated to the temperature, and they are very sensitive to changes in weather, even from hour to hour (Burn & Underwood 2001; Krebs 1985). Habitat variation must also be considered in the sampling designs when the species in question utilises heterogeneous habitats. A stratification sampling, as used here, ensures adequate coverage of all habitat types (Buckland *et al*. 1993; Krebs 1985). If a species occurs at varying densities in different habitats, it is advised to increase sampling in this habitat type (Sutherland 2006), that is why we varied our sampling effort in the different habitats.

On Round Island, total removal plots provided more accurate population size estimates of reptiles differing in macro- and micro-habitat demands, and behaviours. However, if we had initially adopted different methodologies geared towards the different species, we would not have been able to compare abundance estimates between species (Sutherland 2006). We recommend using destructive quadrats in combination with belt transects for species with high densities, such as the Telfair's skink, Bojer's skink and Ornate day gecko, and using distance sampling (Buckland *et al*. 1993) for cryptic species or species at lower densities, namely the Bouton's skink, Durrells' night gecko, Guenther's gecko and Keel-scaled boa. As for cryptic or low density species, distance sampling might be better. In addition, population estimates should be calculated only at the time when they are active as we have done in this study. Based on our data, the Telfair's skink and Ornate day gecko should be monitored from 6:00 to 22:00, the Bojer's and Bouton's skinks from 6:00 to 18:00, the Keel-scaled boa and Durrells' night gecko from 18:00 to 22:00, and the Guenther's gecko from 10:00 to 22:00.

Distance sampling is an extension of the line transect method, where the observer walks along a line, and records the distance of an animal to the transect line. This method takes into account the tendency of detecting animals closer to the transect line easier than those further. This method has been proven to accurately estimate the population size of a variety of cryptic species and species occurring at low densities (Buckland *et al*. 1993). However, it is very time- and resource- consuming, especially when monitoring species with high population densities.

Future work should test the accuracy of the here proposed method for ecologically sensitive areas by comparing population estimates gained by this method with those attained by large-scale total removal plots. Furthermore, a comparative study is advised to investigate the differences in population estimates calculated from a combined belt transect/ total removal plot sampling, as proposed here, with a combined distance sampling/ total removal plot approach, while evaluating the time and resource costs of each method. Such knowledge

would greatly benefit reptile conservation projects and long-term monitoring programs relying on accurate but least destructive and cost intensive population estimate sampling protocols.

This study is the first long term study of the absolute population estimate for all the reptiles in all the habitats found on Round Island at both adult and juvenile sizes. The densities varied according to the species, age, habitats and months. Temporal and spatial variations of the reptiles' population are thus apparent. Our estimates for certain species are quite similar to the estimates found by some studies (Korsos & Trocsanyi 2001; Pernetta 2004), but not all (Bullock 1986; Dulloo *et al*. 1999; Nichols & Freeman 2004; North *et al*. 1994). The short term nature, different methodologies or spatial limitation of other studies may explain this, as well as our method not being appropriate for determining population estimates of some species, such as the Bouton's skink.

Furthermore, it is generally important to measure temperature and rainfall in monitoring studies to be able to compare the data among years differing in climatic factors or among sites differing in climatic variables. We propose that the combination of belt transects and destructive sampling are an ideal method to estimate reptile populations on Round Island and in "sensitive" ecosystems, were large destructive quadrats are not feasible, such as protected areas. In any reptile population estimate studies the key factor to consider are (1) the cryptic nature of reptiles by conducting destructive quadrats and generating a correction factor (2) temporal variation, (3) spatial variation, (4) reptile activity patterns, and (5) abiotic factors.

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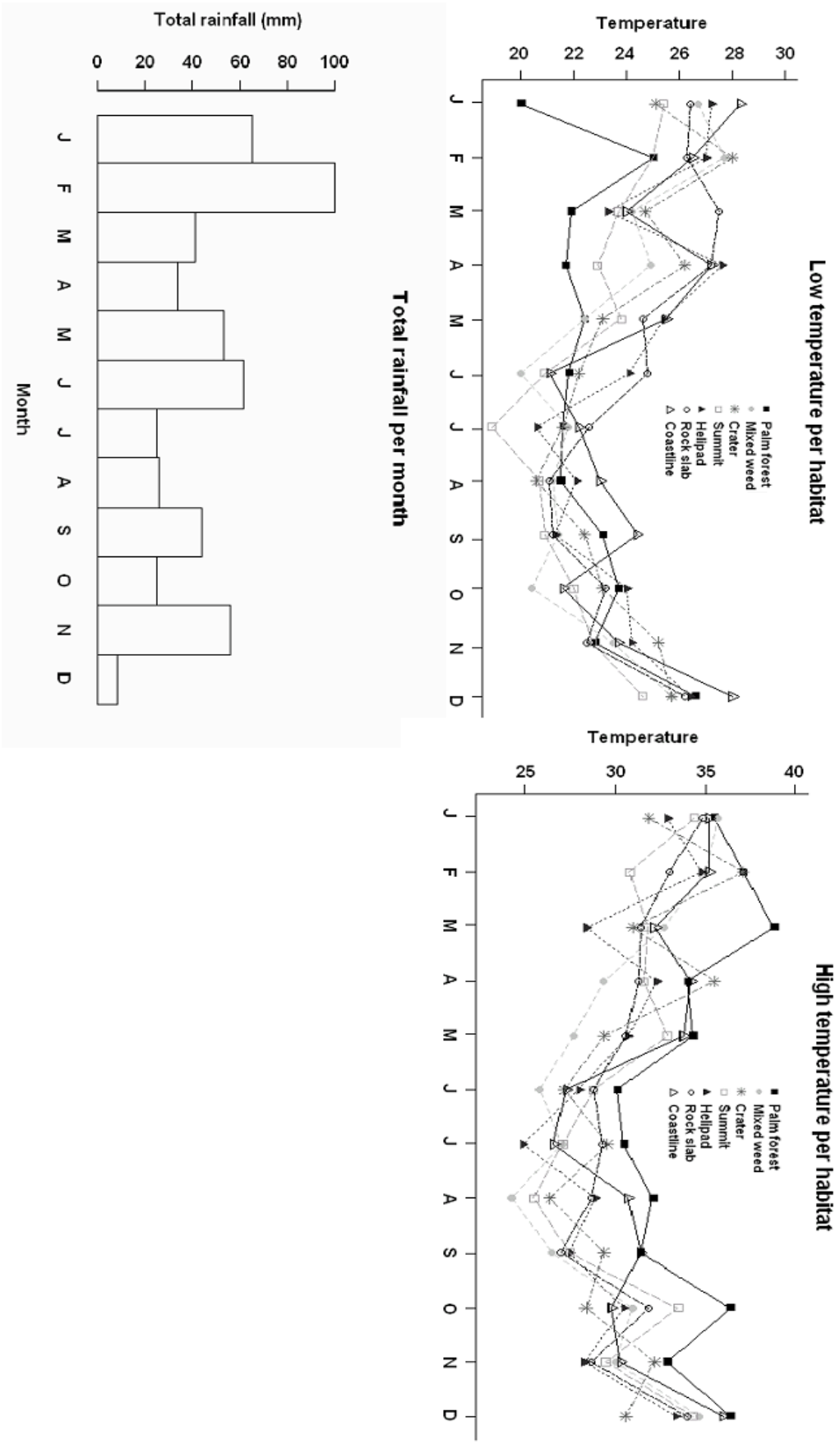
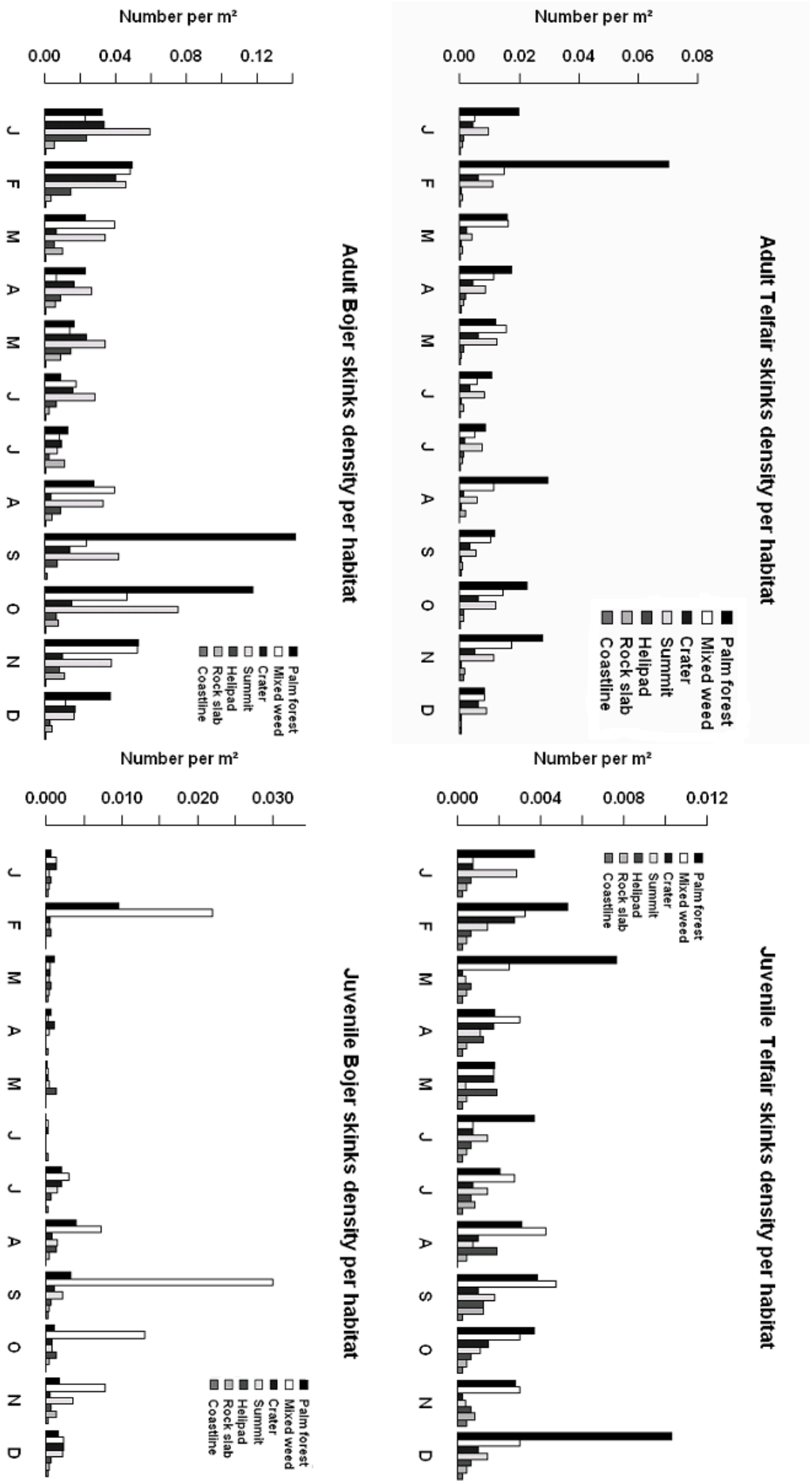
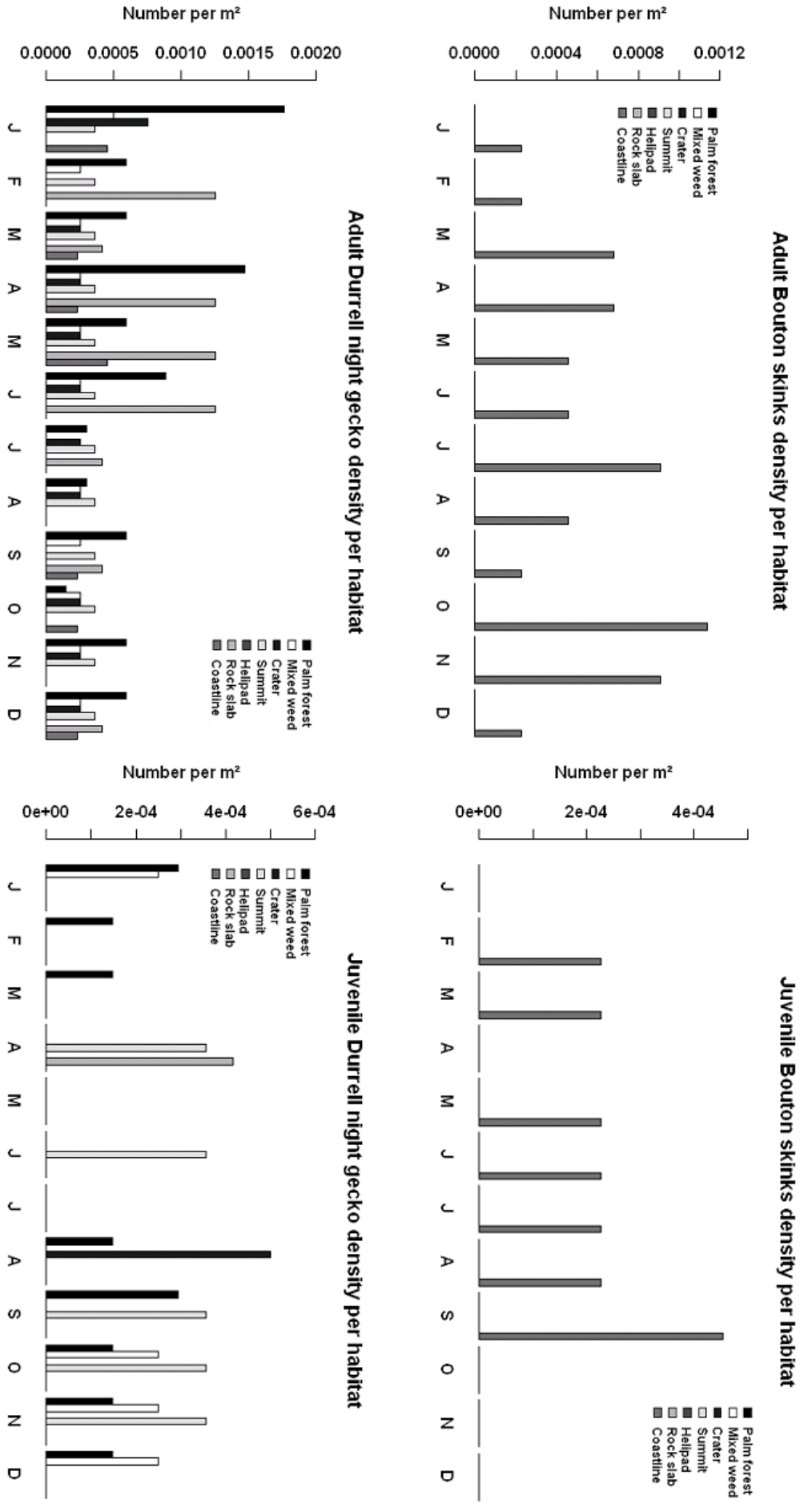
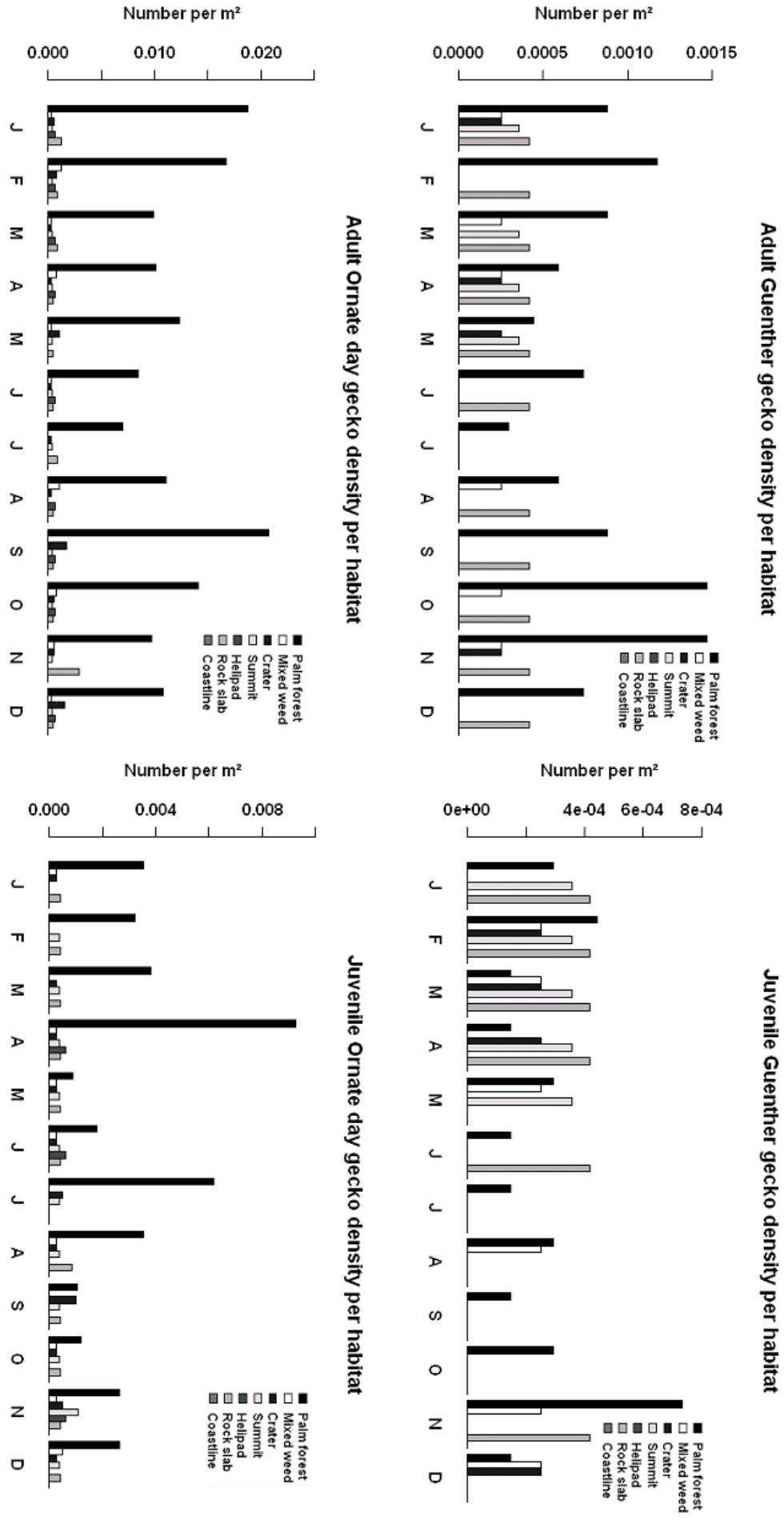
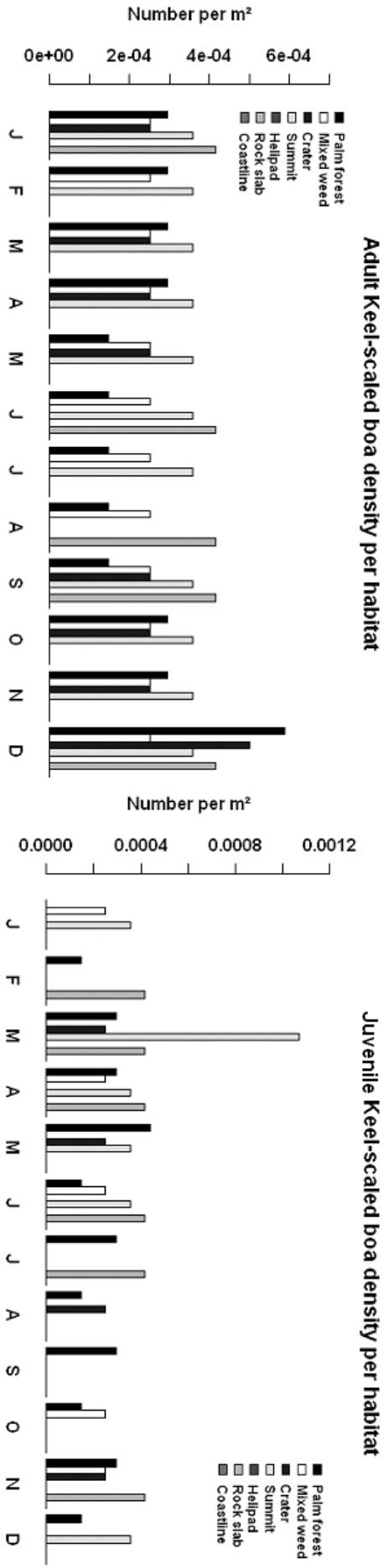
Appendix I: Variation in rainfall (not shown to habitat scale), high and low temperatures, population densities (per m^2) of the seven reptile species within the seven Round Island habitats over one year. Enlarged illustration of Figure 4.




Adult Telfair skinks density per habitat
Number per m²
0.00
0.02
0.04
0.06
0.08
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Adult Bojer skinks density per habitat
Number per m²
0.00
0.04
0.08
0.12
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Telfair skinks density per habitat
Number per m²
0.000
0.004
0.008
0.012
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Bojer skinks density per habitat
Number per m²
0.000
0.010
0.020
0.030
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline


Adult Bouton skinks density per habitat
Number per m²
0.0000
0.0004
0.0008
0.0012
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Adult Durrell night gecko density per habitat
Number per m²
0.0000
0.0005
0.0010
0.0015
0.0020
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Bouton skinks density per habitat
Number per m²
0e+00
2e-04
4e-04
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Durrell night gecko density per habitat
Number per m²
0e+00
2e-04
4e-04
6e-04
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline


Adult Guenther gecko density per habitat
Number per m²
0.0000
0.0005
0.0010
0.0015
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Adult Ornate day gecko density per habitat
Number per m²
0.000
0.010
0.020
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Guenther gecko density per habitat
Number per m²
0e+00
4e-04
6e-04
8e-04
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Juvenile Ornate day gecko density per habitat
Number per m²
0.000
0.004
0.008
J F M A M J J A S O N D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline


Number per m²
0e+00
2e-04
4e-04
6e-04
J
F
M
A
M
J
J
A
S
O
N
D
Palm forest
Mixed weed
Crater
Summit
Helipad
Rock slab
Coastline
Adult Keel-scaled boa density per habitat
Number per m²
0.0000
0.0004
0.0008
0.0012
Juvenile Keel-scaled boa density per habitat

CHAPTER 3

Temporal variation in the diet composition, electivity and diet overlap of the reptile assemblage of Round Island, Mauritius

Chapter 3

Temporal variation in the diet composition, electivity and diet overlap of the reptile assemblage of Round Island, Mauritius

Abstract

Translocation is a feasible solution to prevent the extinction of some species, by spreading their distribution. Prior to relocating a species, it is critical to understand their biology and ecology. In this study, we investigated the diet of all the Round Island reptiles, one boa, three skinks and three geckos over one year as this is of significance to choosing suitable recipient islands and for comparative post-translocation analyses. The variation in composition of chosen food items, electivity indices and dietary niche overlap between the different reptiles was determined. We report monthly interspecific and intraspecific (differentiated by age class) diet differences, number of prey items chosen, electivity indices and dietary niche overlap for most lizard species. The exception was the Keel-scaled boa, the top predator. Diet composition, number of prey chosen, electivity indices and dietary niche overlap was correlated to the size and weight of the reptiles. Invertebrates constituted a large proportion of the diet of lizards. We conclude that to get a good overview of the diet of these reptiles, it is really important to sample the whole year due to the very high monthly variation in diet composition, number of prey chosen, electivity indices and dietary niche overlap. If the reptiles are translocated, the recipient island should therefore have an abundant invertebrate fauna. In general, the relocation of larger (> 10 cm) reptiles' species should be favoured because of their broader diet. The omnivorous skinks are prime candidates for relocation, as their greater flexibility in diet will allow them to more readily adapt to a recipient site.

Introduction

The extinction of species in the tropics is proceeding rapidly as a result of habitat destruction, fragmentation and the introduction of invasive alien species (Reaser *et al*. 2007). Consequently, highlighting the necessity to conserve threatened species (Gipps 1991). However, before any conservation measures are adopted, detailed studies of the biology and ecology of wild populations are required (Dodd & Seigel 1991; IUCN 1996).

Mauritius once had one of the most diverse reptile faunas in the world (Arnold 2000). However, since the arrival of the first European colonisers (1598), Mauritius has experienced high rates of extinction caused by extensive habitat destruction and the introduction of numerous non-native species (Cheke & Hume 2008). Consequently, more than 60% of the endemic reptile fauna has been lost from the main island, with some surviving species now restricted to a few offshore islands (Arnold 2000). These reptile species are highly endangered and at risk from further anthropogenic and stochastic perturbation (Caughley 1994). Round Island is the only island to have retained 70% of its original reptile fauna, due to a lack of introduced predatory mammals and reptiles (Arnold 2000). One strategy to minimise the risk of species extinctions is to establish secondary populations by translocation. This has recently been done with Telfair's skinks (*Leiolopisma telfairii*), which were until recently found only on Round Island. In February 2007, 250 Telfair's skinks were relocated to Gunner's Quoin, where they once occurred (Arnold 2000; Cheke & Hume 2008), and 190 to Ile aux Aigrettes, which offers a suitable habitat and is predator-free. These initial translocations were the basis for future relocations of other Round Island endemic reptiles (Cheke & Hume 2008). However prior to translocation, a detailed investigation of their diet, shelter and microhabitat requirements is critical to identify the best recipient habitats (Dodd & Seigel 1991).

Obtaining adequate nutrition is fundamental to the fitness of reptiles (Stephens & Krebs 1986). Most animals feed selectively (Arnold 1993; Caraco & Gillespie 1986; Greene 1986; Nakano *et al*. 1999; Schoener 1971). Many factors, such as an ontogenetic shifts in prey preferences, body size, sex and foraging tactics, affect reptile diet (Huey & Pianka 1981). Ultimately, the jaw size influences or at least limits the type and size of prey that can be ingested. If morphological differences between genders and age classes exist, this may result in differential diet (Preest 1994). Dietary composition can vary enormously even among individuals within a population; this variation remains unclear for most organisms (Nakano *et al*. 1999). Diet ultimately defines an organism's trophic niche, and has significant implications for ecological processes at many levels (Charnov 1976; Holling 1966).

To forage efficiently, animals adapt their behaviour to detect and respond to differences in food quality, patterns in food dispersion, and changes in resource availability (Eason 1990; Eifler 1995). Furthermore, the selection of foraging locations might be based on intraspecies or interspecies competition, and predation risk (Elchuk & Wiebe 2002; Vlasman & Fryxell 2002). Optimal diet models have shown that more energy or nutrients can be assimilated when a mixed diet rather than a single food is eaten: the "nutritional wisdom"

model (Alm *et al*. 2002; Dearing & Schall 1992; Eifler 1995; Randolph & Cameron 2001). This strategy is important in reptile diets, when choice is influenced by nutrient content (Randolph & Cameron 2001).

Since dietary decisions are based on a multitude of factors, we investigated how dietary preferences varied among the different reptile species on Round Island, an island whose fauna is dominated by reptiles. This is the first study to monitor the diets of all the Round Island reptile species at two different life stages, juvenile and adult, for a period of twelve months and in all of the seven habitats on the island. Previous studies were limited to several weeks and localities; thereby lacking annual temporal and spatial variation. No previous studies on Round Island have investigated resources availability before. Data for entire assemblages of reptiles are extremely rare (Rodda *et al*. 2001). This study will broaden our understanding of the feeding ecology of these species and provide valuable information required when reinstating populations on islands within the species' historical range.

To investigate diet selection, we determined how much prey items were consumed per species and if this varied between, the species, age and per month. From the diet composition, we will be able to construct the food web structure of the Round Island reptile assemblage using the approach of separating adult and juvenile reptiles. We also determined if the reptiles were omnivores or specialist. We calculated electivity indices, a measure of the utilisation of food types in relation to their abundance or availability in the environment (Lechowicz 1982), the less the reptiles are selective, the more adaptable they would be to new habitats. Diet overlap (Pianka 1973) between the different reptile species was determined to ensure that reptiles with highly overlapping diets are not translocated to the same site, where they would compete for the same food resources, and thereby potentially limit the successful establishment of each other. This is especially important for more selective species, which are considered less adaptable in terms of food availability. We investigated, if annual temporal and spatial variation as well as age separation affects prey choice, diet composition, electivity indices and dietary niche overlap. As body morphometrics are usually correlated to diet selection (Preest 1994; Woodward *et al*. 2005), we investigated if diet composition, electivity indices and dietary niche overlap were correlated to body morphometrics. The aim of the study is to explore dietary relationships among reptiles on Round Island to better understand patterns of community structure and function. The new insights on dietary relationships generated by this study should help conservationists to identify the best recipient habitats in terms of feeding ecology for the successful translocation of the Round Island reptiles.

Materials and methods

Study species

The Round Island herpetofauna is outstanding (North *et al*. 1994): eight species are recorded, of which seven are Mascarene endemics and four are now confined to Round Island (North *et al*. 1994; Vinson 1975). However, within the last few decades, the adverse impact of rabbits and goats has caused the probable extinction of the Burrowing boa, *Bolyeria multocarinata,* last seen in 1975 (North *et al*. 1994).

The Round Island herpetofauna is composed of 3 skinks: Telfair's skink (*Leiolopisma telfairii)*, Bojer's skink (*Gongylomorphus bojeri*) and Bouton's skink (*Cryptoblepharus boutonii*), 3 geckos: Guenther's gecko (*Phelsuma guentheri*), the Ornate day gecko (*Phelsuma ornata*) and Durrells' night gecko (*Nactus durrelli*) and 2 snakes (boa): the Keel-scaled boa (*Casarea dussumerii*) and the Burrowing boa (*Bolyeria multocarinata*).

Study sites

The study was conducted on Round Island. Round Island (57°47□03□E, 19°54□03□S) is a basaltic volcanic cone, located 22.4 km off the north coast of Mauritius (Merton *et al*. 1989). Mauritius (57°33□02□E, 20°17□03□S) is roughly 830 km east of central Madagascar in the Indian Ocean (Fig. 1) and is part of the Mascarene archipelago, together with the neighbouring islands of Réunion and Rodrigues.

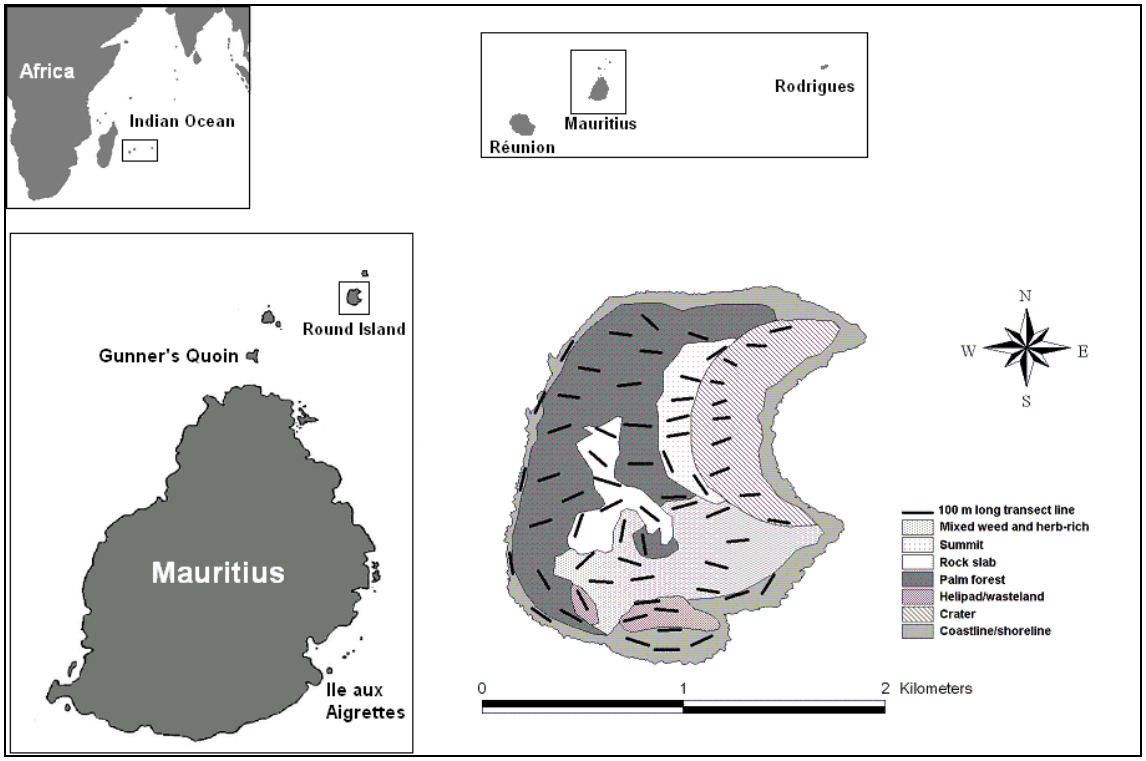


Figure 1 Location of Mauritius and Round Island, showing the 7 habitats and the location of the 65 transects.

Round Island covers an area of 215 ha and rises to 280 m above sea level (Johansson 2003). The island was divided into seven distinct habitat types according to vegetation and substrate (modified and updated from (Johansson 2003)) (Fig. 1 & Table 1).

Table 1. Surface area in hectares of the seven habitats on Round Island and the number of belt transect line set up in each habitat.

Habitat	Surface area /ha	Number of transect lines
Palm forest	65.94	17 transects
Coastline/shoreline	40.36	11 transects
Mixed weed and herb-rich	36.68	10 transects
Crater	34.60	10 transects
Summit	15.85	7 transects
Rock slab	13.27	6 transects
Helipad/wasteland	8.30	4 transects

Quantification of food availability

To determine food choice relative to availability (electivity), the food items (reptiles, plants and invertebrates) were quantified in the different habitats monthly. Since the seven habitats vary in size (Table 1), stratified sampling was done. A total of 65 100m long belt transects were randomly distributed using an extension Arcview 3.2 and permanently established across the seven habitats, based on the surface area of each habitat (Fig. 1 & Table 1). The distribution and position of transects was generated using an extension of Arcview 3.2 (ESRI), the Random point generator. In our case, the criteria for the positioning of the

transects line were: each transect was placed at fix distance from each other based on the size of the habitat and the orientation was set to go up the slope of the island.

Ten 1m^2 quadrats were established at ten metre intervals on consecutive sides of the permanent transect line in which plant and invertebrate resources were quantified. In each quadrat, all plant individuals and the number of flowers and fruits were counted. Invertebrate composition and abundance was determined using three methods: direct observation, sweep netting and pitfall traps. Direct observation was suitable for slow-moving ground-dwelling insects, while sweep netting is considered a reliable method for trapping invertebrates that hide, but fly up when disturbed. A sweep net was swept over each quadrat four times in quick succession. Crawling invertebrates were trapped using 10 unbaited pit fall water traps (with a drop of washing-up liquid) which were placed beside each quadrat for 24 hours. Each pit fall trap was assumed to represent 1m^2. At night, the quadrats were searched with the aid of a head torch. In addition, a 1 m^2 white cloth was placed beside each of the quadrats for 5 minutes and all invertebrates on it counted.

All reptiles and birds encountered within a 2 m belt on either side of the transect line were recorded and assigned to an age class (adult or juvenile). In each habitat, transects and their respective quadrats were monitored once a month, at regular intervals throughout the day (from 6:00 to 10:00, 10:00 to 14:00, 14:00 to 18:00 and 18:00 to 22:00) to incorporate daily variation in animal activity.

Our estimates of reptiles, birds and invertebrates were refined with a calibration index. This was determined by destructive sampling (Rodda *et al*. 2001). A greased animal-proof aluminium barrier, 0.5 m in height, enclosing 1 m^2 was buried in the ground around a randomly chosen quadrat close to the transects line to a depth of 0.1 m (see Rodda, Campbell & Fritts 2001 for further details of the method). All reptiles, birds and invertebrates within the quadrat were counted to evaluate a precise value of their density. All matter within the quadrat was then searched and removed to obtain a total count of all the reptiles, birds and invertebrates, which may have been overlooked by simple direct counts. Five destructive quadrats were sampled monthly, at regular intervals throughout the day (from 6:00 to 10:00, 10:00 to 14:00, 14:00 to 18:00 and 18:00 to 22:00) in random quadrats close to transects lines in each habitat. The correction factor was obtained by dividing the number of individuals of each species observed after destruction, by the number observed before destruction. The reptiles, birds and invertebrates estimate from the belt transect and quadrats were then corrected by multiplying the number of reptiles found in each habitat by its respective correction factor.

Population estimates of reptiles, birds, plants and invertebrates per habitat are expressed as number per m^2. For the invertebrates, the number per m^2 was obtained by adding the number obtained per m^2 by direct observation, sweep netting and pitfall traps methods.

Quantification and qualification of reptile food intake

Faecal sampling was used to qualify and quantify reptile food intake. A maximum of 10 faecal samples were collected from each habitat for both adults and juveniles of each species; at regular intervals throughout the day (from 6:00 to 10:00, 10:00 to 14:00, 14:00 to 18:00 and 18:00 to 22:00) in areas close to transects lines (Fig. 1). A total of 4,311 faecal samples were collected for all seven reptile species from July 2006 to June 2007. We collected and analysed 1,498 Telfair's skink faecal samples (843 adults, 655 juveniles), 1,082 Bojer's skink faecal samples (776 adults, 306 juveniles), 78 Bouton's skink faecal samples (66 adults, 12 juveniles), 708 Ornate day gecko faecal samples (469 adults, 239 juveniles), 247 Guenther's gecko faecal samples (176 adults, 71 juveniles), 443 Durrells' night gecko faecal samples (405 adults, 38 juveniles) and 255 Keel-scaled boa faecal samples (176 adults, 79 juveniles). Samples were obtained by massaging a reptile's abdomen (Legler 1977), and matter individually preserved in 80% ethanol. The body weight (g), snout to vent length (mm) and tail length (mm) of each of the faecal donor was recorded. Each faecal donor was marked to ensure that the same individual was not sample twice per sampling round. The percentage of each food item in the diet was analysed using a dissecting microscope. Frequency of occurrence data was calculated as percentage of occurrence (Lockie 1959), where the frequency with which each food item occurred is expressed as a percentage of the total number of occurrences of all food items, rather than a percentage of the total number of faeces samples. We believe the former measure to be more meaningful in terms of diet composition as it expresses the frequency of a food item relative to the other food items recovered in the faecal samples.

Plants, reptiles and birds were determined to species level. Fruits and flowers of plants analysed as separated prey items. No other plant parts were found in the diet of the reptiles. Reptile and bird items were assigned to the two age classes adults and juveniles and separately analysed. Invertebrates were identified to morpho-species level and grouped back to order for analysis and to facilitate comparisons with other past dietary studies. To facilitate the invertebrate identification from the faecal samples, a collection of 419 invertebrate morpho-species was established and documented pictorially. Identification was further

enhanced by dismantling invertebrates and/or feeding soft-bodied invertebrates, such as moths and flies, to the reptiles and identifying the resultant matter.

Statistical analyses

Dietary preference was determined by comparing the relative abundance of food items within the diet of the reptile species to their relative abundance of these food items within the environment using Vanderploeg & Scavia's relativised electivity index E* (Krebs 1999; Lechowicz 1982; Vanderploeg & Scavia 1979) : $E^* = \frac{W_i - (1/n)}{W_i + (1/n)}$ where W_i is calculated as $W_i = \frac{ri/pi}{\sum ri/pi}$, r_i is the relative abundance of a prey category in the diet, p_i is the relative abundance of a prey category in the environment and n is the number of prey categories considered. Electivity index values close to +1 indicate active selection, close to -1 indicates avoidance of prey items and values close to 0 show random selection.

Comparing a series of electivity indices Lechowicz (1982) recommends to use this index as it embodies a measure of the feeder's perception of a food's value as a function of both its abundance and the abundance of other food types present, i.e. selection of a food item is relativised against other item availability. It is meaningful for comparisons among species and temporal scales (Lechowicz 1982).

Diet overlap was calculated using Pianka´s (1973) niche overlap index O_{12}:

$$O_{12}=O_{21}=\frac{\sum_{i=1}^{n} P_{2i}\,P_{1i}}{\sqrt{\sum_{i=1}^{n} (P_{2i}?)(P_{1i}?)}}$$

where p_{1i} and p_{2i} are the resource utilisations for species 1 and 2 and n is the number of prey categories considered. The Pianka's niche overlap index, calculate the percentage of niche overlap (diet overlap based on occurrence in diet) between two species using pairwise comparison. The computer package EcoSim700 (Gotelli & Entsminger, 2001) was used to analyse monthly variation in diet overlap.

To explore the effect of species identity on diet composition, number of food items consumed, electivity and diet overlap, generalised linear models (GLMs) were fitted. Quasi-Poisson errors were used when analysing variation in the dependent variables number of food items and electivity, while using Binomial errors in the analyses of the proportional dependent variables diet composition and diet overlap. Since species identity was highly

significant in explaining variation in the dependent variables, separate GLMs for each species and age class (adult and juvenile) were fitted to investigate the effect of month on diet composition, number of food items consumed, electivity and diet overlap. GLMs were also used to analyse whether diet composition, number of food items consumed, electivity and diet overlap varied between adults and juveniles of a species To account for statistical overdispersion, mean deviance changes were compared with *F*-tests (Crawley 2005).

GLMs with quasi-Poisson errors were fitted to investigate the effect of differences in weight and snout to vent length (Svl) between species on the number of food items consumed, trophic level in the food web, electivity, whereas a GLM with Binomial error was used to analyse the effect of these explanatory variables on diet overlap. To analyse the influence of omnivory (omnivorous vs. not omnivorous species) on the trophic level in the food web, electivity and diet overlap, GLMs were fitted,

For all analyses the software package R.2.7.0 (R Development Core Team 2008) was used.

Results

Diet composition

Diet composition significantly varied between species, ($F_{6,1216}$= 81.93, P<0.0001, Fig. 2) among months and between adult and juvenile stage (all P<0.0001, see Fig. 3 & Appendix I).

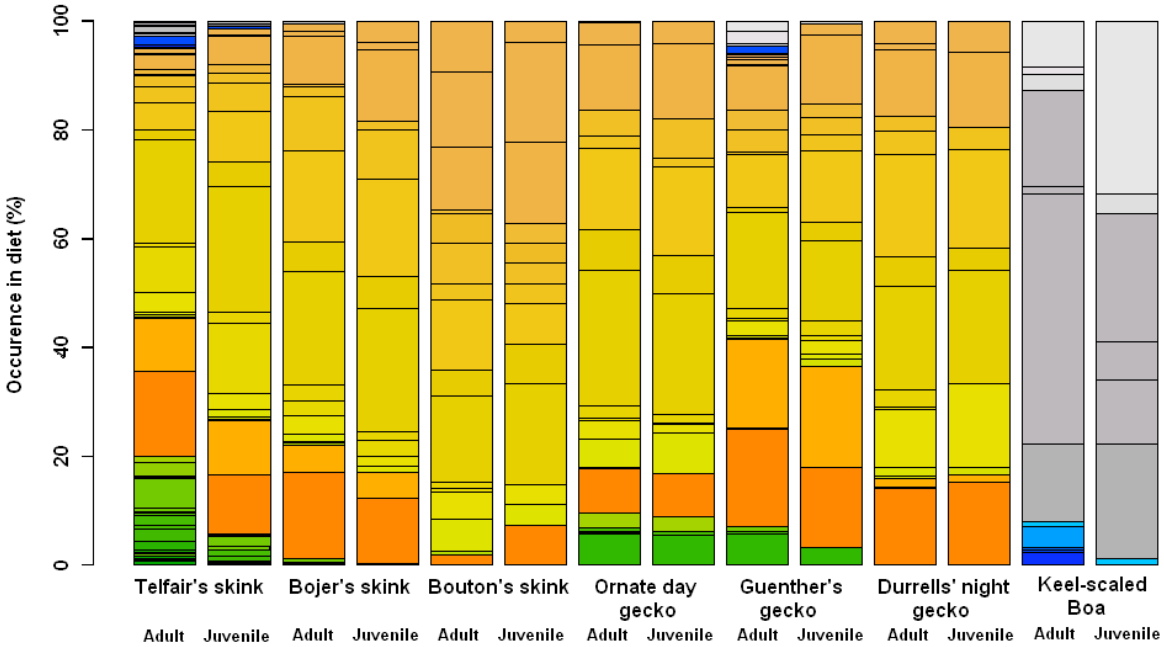


Figure 2. Percentage diet occurrence for the Round Island reptiles over a period of one year determined from a total of 4,311 faecal samples. The green sections represent the food items of plant origin; the orange sections, invertebrates; the blue sections, seabirds; and the grey sections, reptile origin.

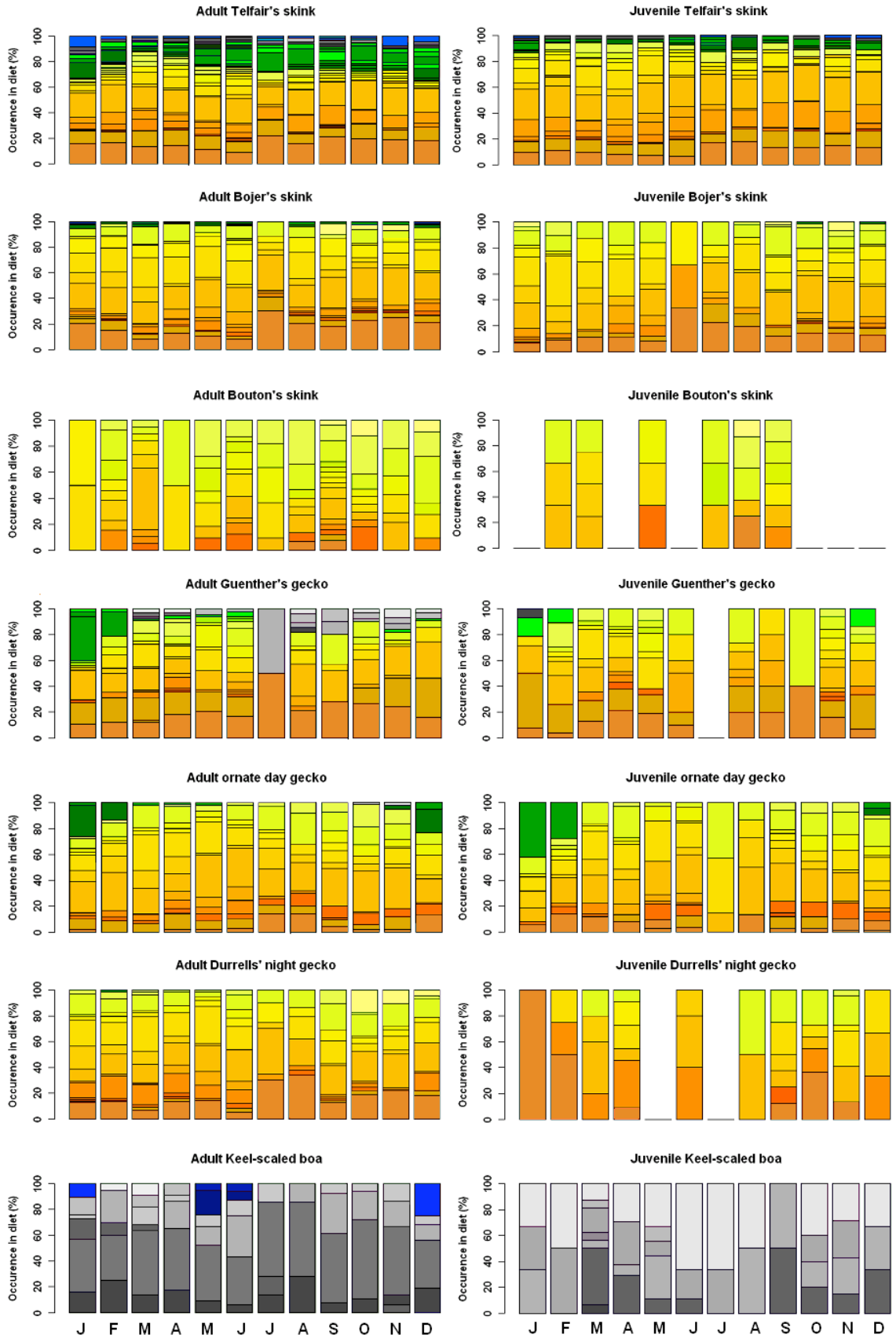


Figure 3. Percentage diet occurrence of the Round Island reptiles over a period of one year. The green sections represent the food items of plant origin, the orange sections invertebrates, the blue sections seabirds and the grey sections reptile origin.

The analysis of the diet composition of the Round Island reptile assemblage demonstrates that Telfair's skink, Bojer's skink, Ornate day gecko and Guenther's gecko are omnivorous, consuming invertebrates, plant matter, birds and reptiles. Bouton's skink and Durrells' night gecko are strictly insectivorous consuming only invertebrates. Adult Keel-scaled boas are strictly carnivorous consuming both reptiles and birds, while juvenile boas are strictly saurivorous consuming only reptiles (Fig. 2 & 3 & Table 2). For all reptile species but the Keel-scaled boa, invertebrates were the most important component of the diet compromising more than 75 % of their diet (Table 2).

The diet composition of omnivorous reptiles (Telfair's skink, Bojer's skink, Ornate day gecko and Guenther's gecko) was relatively constant over time with invertebrates dominating the monthly diet, and plants and reptiles the remainder. However, between November and February, the importance of seabird food items increased for the omnivores. The diet composition of strictly insectivorous (Bouton's skink and Durrells' night gecko) and the boa did not show significant variation during these months (Fig. 3).

Table 2. Overall percentages of diet constituents for the juvenile and adult Round Island reptiles.

Reptile species	Age	Plants	Invertebrates	Reptiles	Birds
Telfair's skink	Adult	19.90	75.11	2.28	2.71
Telfair's skink	Juvenile	5.65	93.03	0.74	0.58
Bojer's skink	Adult	1.13	98.40	0.28	0.19
Bojer's skink	Juvenile	0.29	99.71	0	0
Bouton's skink	Adult	0	100	0	0
Bouton's skink	Juvenile	0	100	0	0
Ornate day gecko	Adult	6.87	92.88	0.26	0
Ornate day gecko	Juvenile	6.07	93.93	0.00	0
Guenther's gecko	Adult	7.10	85.98	6.17	0.75
Guenther's gecko	Juvenile	3.32	96.21	0.47	0
Durrells' night gecko	Adult	0.09	99.91	0	0
Durrells' night gecko	Juvenile	0	100	0	0
Keel-scaled boa	Adult	0	0	93.02	6.98
Keel-scaled boa	Juvenile	0	0	100	0

Food items consumed

The Round Island reptile assemblage consumed 92 different food items. The Telfair's skink consumed most food items (68 ± 12 different items per month), while the lowest number of different food items was found in the diet of the Keel-scaled boa (3 ± 1 different items per month) (Fig. 4 & Appendix II).

The number of food items consumed varied significantly among reptile species ($F_{6,161}$= 125.94, P<0.0001), between adult and juvenile stages ($F_{1,147}$= 90.49, P<0.0001) and during

the year ($F_{11,148}$= 4.62, P<0.0001). The number of different prey chosen could be explained by reptile size ($F_{1,160}$= 10.03, P=0.002) and weight ($F_{1,159}$= 7.81, P=0.006) (Fig 4 & Appendix II).

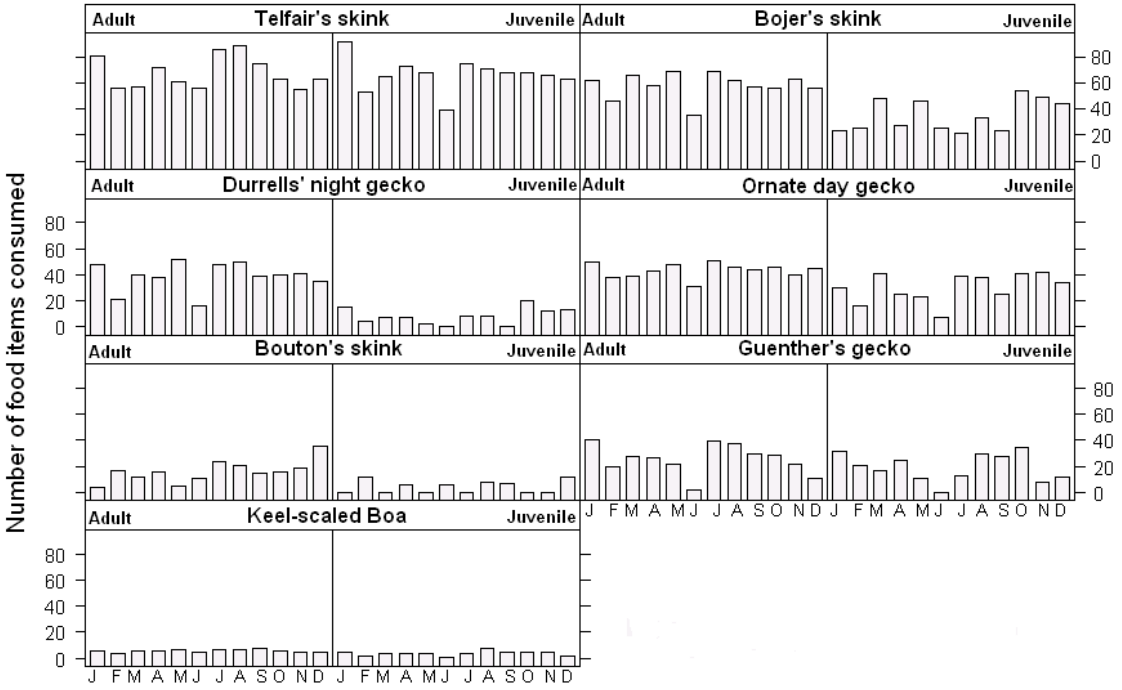


Figure 4. Monthly variation in the number of food items consumed by the Round Island reptiles over a period of one year.

Reptile assemblage structure

According to the observed feeding relationships among the species the Round Island reptile assemblage represents a food web of 6 distinct levels (Fig. 5). The top predator is the adult Keel-scaled boa. The fifth level is composed of the larger adult lizards, the Telfair's skink and Guenther's gecko. The fourth level is occupied by the juvenile Keel-scaled boa. On the third level, there are the smaller adult lizards, the Bojer's skinks, Bouton's skinks, Ornate day gecko, Durrells' night gecko and the juvenile Guenther's gecko and Telfair's skink. The second level is composed of the juvenile Bojer's skinks, Bouton's skinks, Ornate day gecko and Durrells' night gecko. Plant matter, birds and invertebrates constitute the lowest level. Body mass significantly increased with the trophic level of the Round Island reptile food web. ($F_{6,12}$= 28.08, P<0.0001); and their position in the web could be explained by reptile size ($F_{1,12}$= 3.02, P=0.082), but not weight ($F_{1,11}$= 7.81, P=0.434).

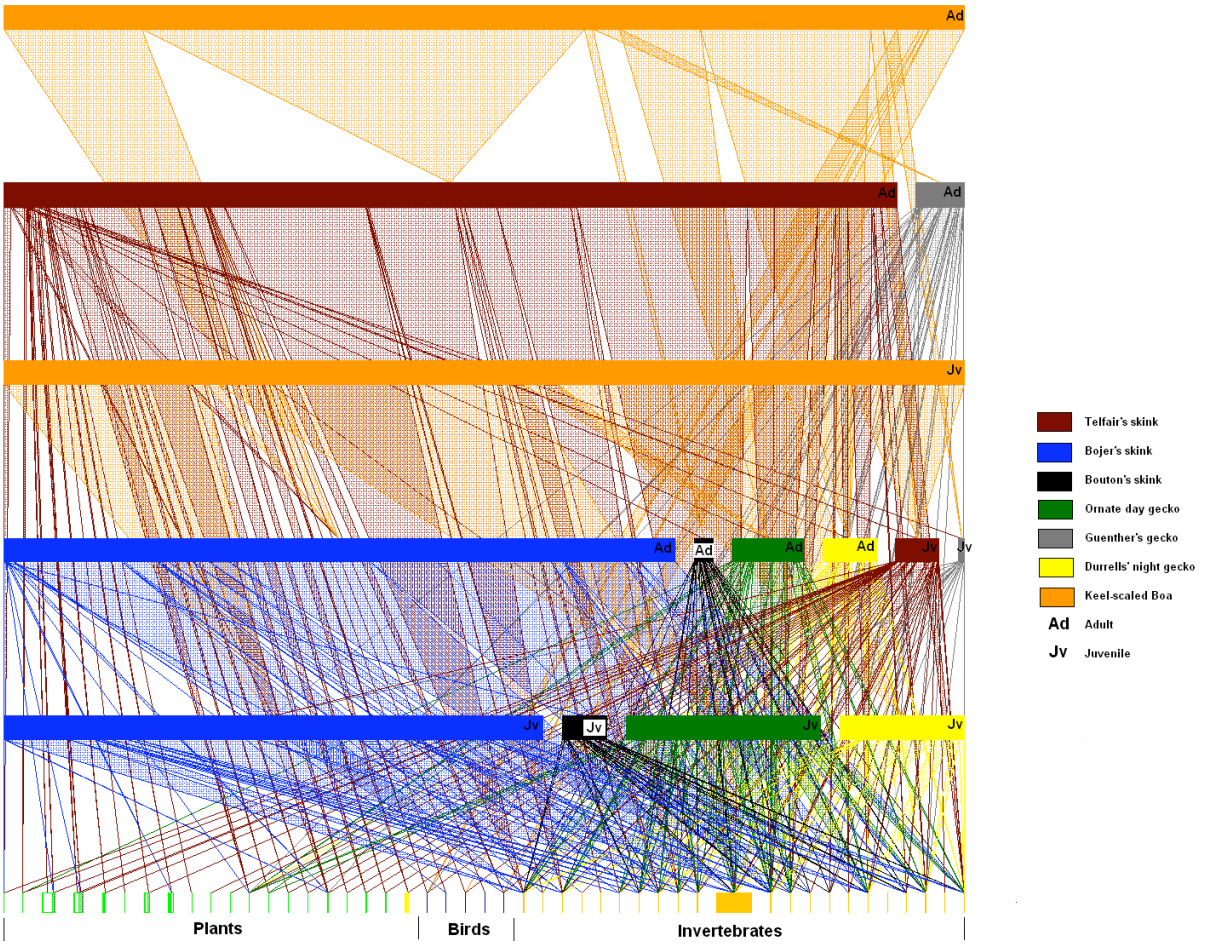


Figure 5. Quantified food web for the reptile assemblage on Round Island over one year. Adult and juvenile stages were separated. Lower bars represent reptile and prey abundance scaled to their levels and the width at the basis of the wedges represents the occurrence of the food item in the diet. The light green sections represent the food items of plant origin; the orange sections, invertebrates; and the blue sections, seabird origin for the lowest level.

Electivity

The occurrence of a food item in the diet indicates diet composition (Fig. 2 & 3), however, hides whether certain food items are randomly selected or specifically chosen. To determine if the reptiles were selective in their food choice, we calculated Vanderploeg & Scavia's relativised electivity index. Vanderploeg & Scavia's relativised electivity index of the pooled data over the whole year differed significantly among species ($F_{6,945}$= 8.27, P<0.0001, Fig 9 & Appendix III) and between adult and juvenile stage ($F_{1,944}$= 3.9, P=0.49, Fig 8 & Appendix III). Although reptiles consumed common foods, their preferences differed.

Despite invertebrates comprising by far the largest proportion of the lizards' diet composition, they were not highly selected, but chosen randomly by adults (Fig. 6). However, juveniles of Bojer's skink, Bouton's skink and Durrells' night gecko selected invertebrates. Highly selected food items were flowers and nectar of *Latania loddigesii* (Arecaceae) and

Lomatophylum tormentorii (Aloeaceae) and most of the food items of bird origin, especially Zebra ground barred doves (*Geopelia striata*) and chicks (Fig. 6).

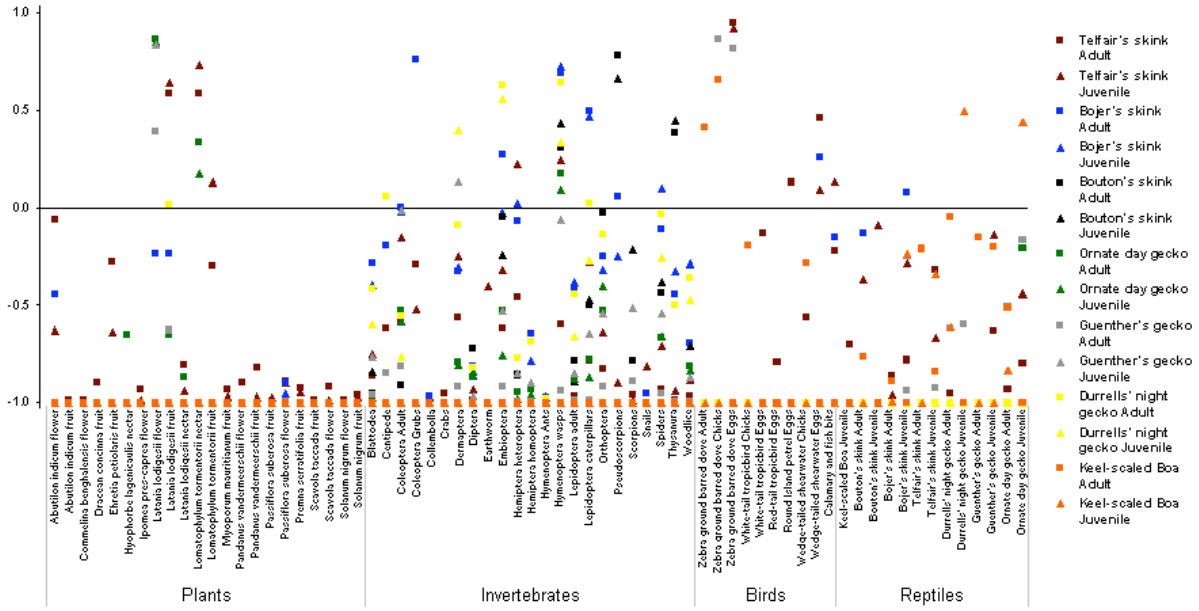


Figure 6. Values of Vanderploeg & Scavia's relativised electivity index for the different food items selected by the seven Round Island reptile species at the adult and juvenile stage over a period of one year. Values close to +1 indicate active selection , values close to -1 indicate avoidance of prey items and values close to 0 indicate random selection.

Table 3. Summary of the GLMs used to investigate if there was a difference in Electivity between the 12 months of the study period and between adult and juvenile reptiles. Statistical significance on the 0.05 level in bold.

Status	Age	Monthly variation			Age difference		
		d.f.	*F*	*P*	d.f.	*F*	*P*
Telfair's skink	Adult	11,804	1.62	0.089	1,1630	4.15	**0.042**
Telfair's skink	Juvenile	11,804	7.02	**0.029**			
Bojer's skink	Adult	11,804	1.77	0.056	1,1630	5.46	**0.020**
Bojer's skink	Juvenile	11,804	2.09	**0.019**			
Bouton's skink	Adult	11,804	0.74	0.705	1,1630	12.38	**0.0004**
Bouton's skink	Juvenile	11,804	1.45	0.145			
Ornate day gecko	Adult	11,804	1.11	0.352	1,1630	1.12	0.290
Ornate day gecko	Juvenile	11,804	1.71	0.067			
Guenther's gecko	Adult	11,804	0.99	0.458	1,1630	0.38	0.539
Guenther's gecko	Juvenile	11,804	1.36	0.196			
Durrells' night gecko	Adult	11,804	0.84	0.605	1,1630	49.88	**<0.0001**
Durrells' night gecko	Juvenile	11,804	1.22	0.272			
Keel-scaled boa	Adult	11,804	0.32	0.982	1,1630	2.82	0.094
Keel-scaled boa	Juvenile	11,804	0.66	0.775			

In general, the electivity did not vary with month (Table 3 & Fig. 7). Most reptiles were therefore consistently selecting the same food items throughout the year. Only juvenile Telfair's and Bojer's skink significantly changed their food item selectivity with time.

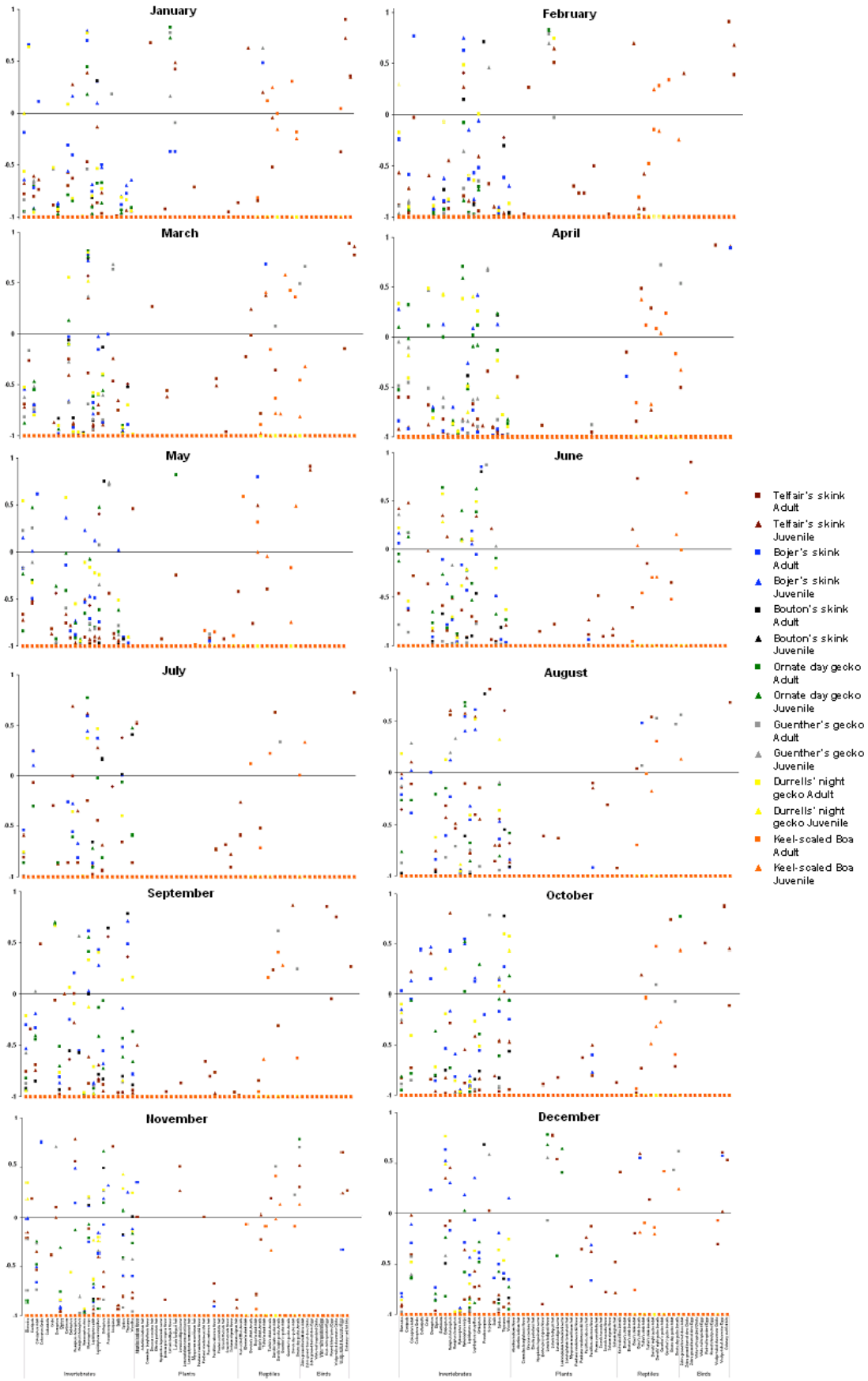


Figure 7. Monthly variation in Vanderploeg & Scavia's relativised electivity index s of the food items found in the diet of the reptile species of Round Island, separated for the adult and juvenile stage. Values close to +1 indicate active selection, values close to -1 indicate avoidance of prey items and values close to 0 indicate random selection.

Electivity significantly differed between adult and juvenile Telfair's skink, Bojer's skink, Bouton's skink and Durrells' night gecko. In contrast, there was no difference in electivity indices between adult and juvenile Guenther's gecko, Ornate day gecko and Keel-scaled boa (Fig. 7 & Table 2). This variation in selectivity between age classes can be explained by the fact that the former species' are omnivores ($F_{1,950}$= 11.66, P=0.0007, Fig. 2). Variation in the size ($F_{1,949}$= 1.17, P=0.279) and weight ($F_{1,948}$= 0.01, P=0.942) between reptiles did not explain variation in electivity for the juveniles and adults

Diet overlap

To determine diet overlap, Pianka's (1973) niche overlap index was calculated. There was a significant difference in the diet overlap of the seven reptiles species (pooled data over the whole year: $F_{6,174}$= 3.03, P<0.008, Fig 11 & Appendix IV). No significant difference in diet overlap was found for the adults and juveniles for each species ($F_{1,180}$= 0.01, P=0.979, Fig 8 & Appendix IV).

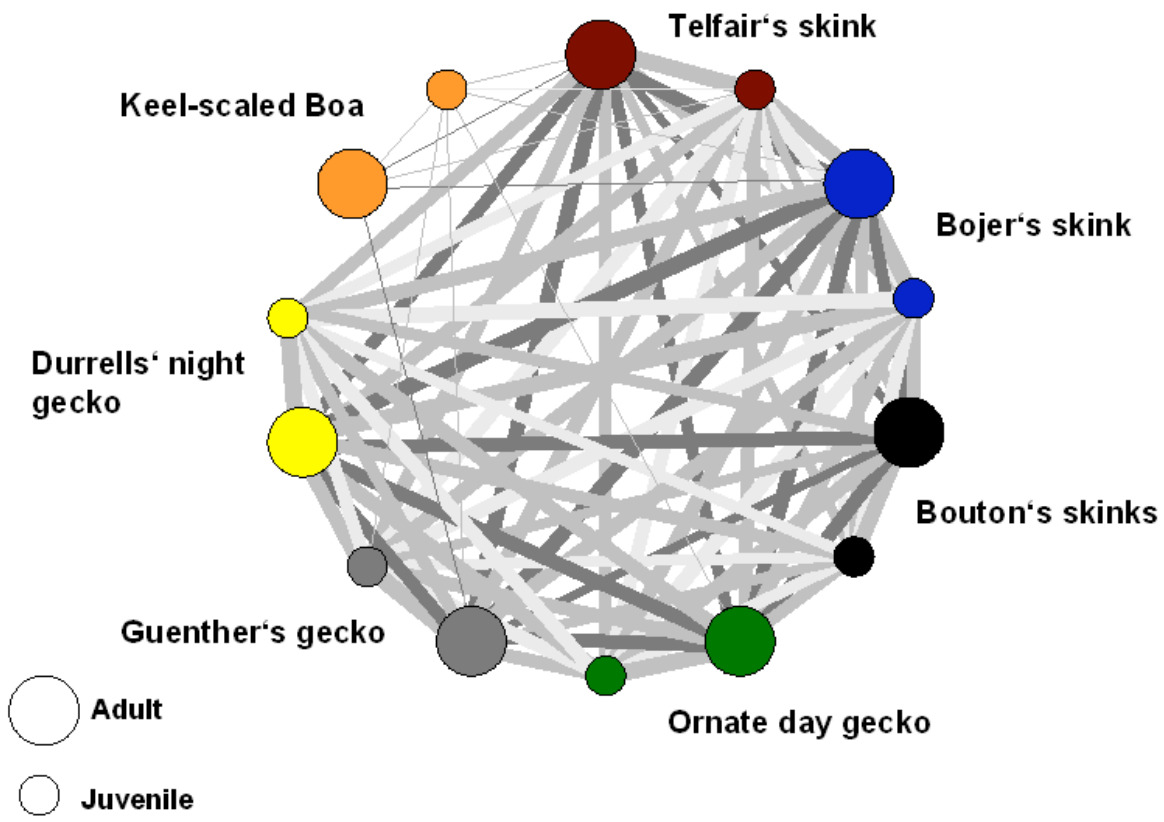


Figure 8. Diet overlap (calculated as Pianka's niche overlap) per year for all adult and juvenile reptiles on Round Island. The thickness of the line indicates the percentage of overlap (thick lines represent high overlap). The pale grey lines indicates overlap between juveniles of different species, grey lines between adults and juveniles, and dark grey lines overlap between adults.

Table 4. Diet overlap (calculated as Pianka's niche overlap) between the seven reptile species of Round Island at the adult and juvenile stages over a period of one year.

Species		Telfair's skink		Bojer's skink		Bouton's skink		Ornate day gecko		Guenther's gecko		Durrells' night gecko		Keel-scaled Boa	
	Age	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Telfair's skink	Adult		High	High	High	Medium	Medium	Medium	Medium	High	High	High	Medium	Low	Low
	Juvenile			High	High	Medium	Medium	High	High	High	High	High	High	Low	Low
Bojer's skink	Adult				High	Medium	Medium	High	High	High	High	High	High	No	Low
	Juvenile					High	High	High	High	High	High	High	High	No	No
Bouton's skink	Adult						High	High	High	Medium	Medium	High	Medium	No	No
	Juvenile							Medium	Medium	Medium	Medium	High	Medium	No	No
Ornate day gecko	Adult								High	High	High	High	High	No	Low
	Juvenile									High	High	High	High	No	No
Guenther's gecko	Adult										High	High	High	Low	Low
	Juvenile											High	High	No	Low
Durrells' night gecko	Adult												High	No	No
	Juvenile													No	No
Keel-scaled Boa	Adult														Low
	Juvenile														

In general, there was a high diet overlap among the lizards, whereas the diet overlap between the Keel-scaled boa and the other lizards was low (Fig 8 & Table 4). Among the lizards only, the Bouton's skink generally showed a relatively low diet overlap with the other lizards. The overlap was higher between adults and juveniles of the same species (Table 4).

Table 5. Summary of the GLMs investigating difference in diet overlap for the seven Round Island reptiles for the 12 different months of the study period and between adults and juveniles . Statistical significance indicated in bold.

Status	Age	Monthly variation			Age difference		
		d.f.	*F*	*P*	d.f.	*F*	*P*
Telfair's skink	Adult	11,153	3.37	**0.001**	1,331	4.79	**0.029**
Telfair's skink	Juvenile	11,156	2.79	**0.003**			
Bojer's skink	Adult	11,156	1.48	0.912	1,334	0.59	0.443
Bojer's skink	Juvenile	11,156	1.09	0.370			
Bouton's skink	Adult	11,156	0.94	0.507	1,334	50.8	**<0.0001**
Bouton's skink	Juvenile	11,156	0.001	**<0.0001**			
Ornate day gecko	Adult	11,156	0.70	0.735	1,334	0.86	0.3548
Ornate day gecko	Juvenile	11,156	0.63	0.8			
Guenther's gecko	Adult	11,156	8.00	**<0.0001**	1,334	5.43	**0.020**
Guenther's gecko	Juvenile	11,156	31.543	**<0.0001**			
Durrells' night gecko	Adult	11,156	0.78	0.663	1,334	9.61	**0.002**
Durrells' night gecko	Juvenile	11,156	124.08	**<0.0001**			
Keel-scaled boa	Adult	11,156	0.98	0.471	1,334	0.51	0.476
Keel-scaled boa	Juvenile	11,156	3.11	**0.001**			

For adult and juvenile Telfair's skink and Guenther's gecko, and juvenile Bouton's skink, Durrells' night gecko and Keel-scaled boa diet overlap with all other reptiles varied among months (Table 5 & Fig. 9). No such pattern among month variation was found for the other reptile groups (Table 5 & Fig. 9). The diet overlap varied significantly with reptile age for the Bouton's skink, Guenther's gecko and Durrells' night gecko (Table 5 & Fig. 9). Monthly variation can be explained by weight ($F_{1,180}$= 49.55, P<0.0001), and the fact that

these species were omnivores ($F_{1,180}$= 41.59, P<0.0001). Reptile size ($F_{1,180}$= 1.12, P=0.29) did not affect the degree of overlap.

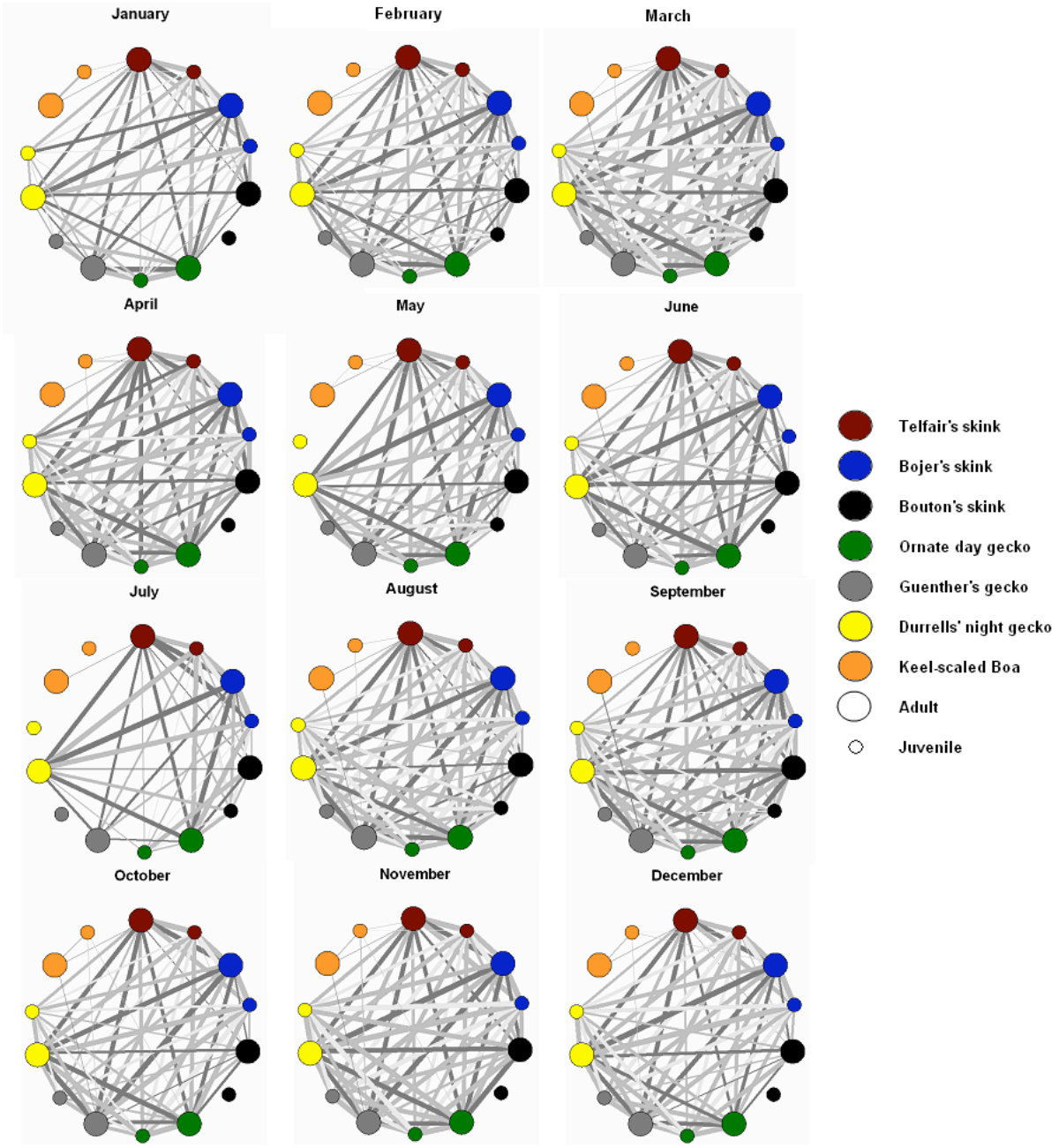


Figure 9. Diet overlap (calculated as Pianka's niche overlap) per month or the Round Island reptile community. The thickness of the line indicates the percentage of overlap (thick lines represent high overlap). The pale grey lines indicates overlap between juveniles of different species, grey lines between adults and juveniles, and dark grey lines overlap between adults.

Discussion

In this study, we found monthly interspecific and intraspecific (differentiated by age class) diet differences, number of prey items chosen, electivity indices and dietary niche overlap for most lizard species; the exception was the Keel-scaled boa. These were correlated to the body morphometrics of the reptiles. Invertebrates constituted a large proportion of the diet of lizards. To get a good overview of the diet of these reptiles, it is really important to sample the whole year due to the very high monthly variation in diet composition, number of prey chosen, electivity indices and dietary niche overlap.

Diets composition, food items consumed and temporal variation

The diets of the Round Island reptiles were studied using occurrence in diet which tends to overestimate the significance of small prey items, such as invertebrates. Nevertheless, it provides comparative data of the diets and of the differences in food item composition among the different reptile species along a temporal scale (Ciucci *et al*. 1996). Despite this overestimation, the invertebrates are the most important food item for almost all reptiles, electivity for those items was generally low and other items more selected when available. The monthly diets of the Round Island reptiles were distinctly different. The number of food items chosen was correlated with body size and weight. The juveniles of each species usually consumed a smaller number of different food items than their adult conspecifics, and the items consumed were usually smaller in size. Gape size restrictions most likely explains this (Preest 1994).

The diets recorded during this study differed in both taxonomic and numeric composition from those reported by previous studies (Bullock 1986; North *et al*. 1994; Vinson 1975; Vinson & Vinson 1969). This can be attributed to the short-term nature of these studies and the large seasonal variability observed in the reptiles' diets, which is common in other lizards (Pianka 1970). The significance of invertebrates in the lizards' diet was confirmed, as well as the specialised nature of the Keel-scaled boa, with the adult feeding exclusively on birds and reptiles and the juvenile exclusively on reptiles.

The Telfair's skink was the most omnivorous, when adult and juvenile diets were grouped. Followed in food item diversity, by the Bojer's skink, Ornate day gecko, Guenther's gecko, Durrells' night gecko, Bouton's skink and finally the Keel-scaled boa. The greatest difference in diets occurred between the Keel-scaled boa and the lizards, in which neither adult nor juvenile stages consumed invertebrates. Adult boas consumed only birds and

reptiles, while juveniles exclusively fed on smaller reptiles. The adult boa is the only reptile on Round Island to consume live seabird chicks and adult and chicks of the Zebra barred ground dove, although the adult Telfair's skink and Guenther's gecko also consumed live adult and chicks of the Zebra ground barred dove.

Summer rains resulted in an increase in the abundance of most food items, and an overall increase in prey biomass available to the lizards. The results suggest a large element of opportunism in the selection of prey, and that changes in the abundance of prey have a large effect on the lizard's diets. The proportion of invertebrates in the diet of most of the Round Island lizards was highest during the driest period of the study (June to September) and lowest when overall prey abundance was high (January to April). Invertebrates were therefore an important food source during dry conditions.

The more closely related lizards on Round Island have a more synonymous diet. This is expected as closely related lizards generally have similar morphological and ecological traits (Huey & Pianka 1981; Vitt & Zani 1996).

Reptile assemblage structure

A clear food web structure exists in the Round Island reptile assemblage. Typically, this assemblage exhibit clear trophic divisions, and is comprised of both generalist and specialist predators (Pianka 1973). These trophic divisions are enhanced when the reptiles are differentiated into adults and juveniles, which are rarely done in assemblage studies (Woodward & Hildrew 2001). However, it is important as relative body-size of the component species of a food web has often been identified as a major determinant of the web structure (Memmott *et al*. 2000) and in determining trophic status (Woodward & Hildrew 2002). Division of species into age classes produced clearer food webs, in which there was a correlation between trophic level and body size and weight. In general, we found that predators were on average larger than their prey, and predator and prey size increased together, as found by (Brose *et al*. 2006).

Woodward *et al*. (2002) found that shared feeding links were common in food webs, as illustrated by the Round Island food web. However, they also found that the taxonomic composition of a predator's diet is a subset of the diet of the next largest predator (Woodward & Hildrew 2002). Since the boa is a specialist species feeding only on birds and lizards, its diet is not a subset of the next lowest predator, and so this does not apply to the Round Island web. Thus the Keel-scaled boa, as the top predator, should not be translocated until there is a well establish and abundant reptile and bird population in the recipient habitat.

Electivity and temporal variation

Application of electivity measures are rare, because it requires quantification of the resources in the environment (Albertoni *et al*. 2003). Over the study year, some patterns emerged; certain plant and bird food items were highly selected. In contrast, reptiles and invertebrates were generally not highly selected. The exotic Zebra ground barred dove adult birds, chicks and eggs were highly selected by the adult Keel-scaled boa, Telfair's skink and Guenther's gecko. High preferences for this small bird may be problematic for the critically endangered Mauritian fody (*Foudia rubia*), an insectivorous, 14 cm tall, forest-living weaver bird (Safford 1997), which will be translocated to Round Island in the near future as a means of expanding their distribution. The fody is smaller than the ground barred dove, so may be predated by these three reptiles. It will be interesting to ascertain how these three reptile species and the fody interact as prior to the extinction of reptiles on mainland Mauritius they would have co-occurred (Cheke & Hume 2008).

Reptile diets showed clear temporal variation. Between December and February, Latania palm (*Latania loddigesii*) flowers and nectar were highly selected by the Telfair's skink, Guenther's gecko and Ornate day gecko. These endemic reptiles are important for the pollination of this endemic palm. During this period, Wedge-tailed shearwater eggs were also highly selected for by the Telfair's and Bojer's skink and chicks by the adult Keel-scaled boa. During the dry months, invertebrates and plants items were more selected than during the rest of the year, especially by the omnivorous species; whereas during the wet months, invertebrates were randomly selected. It is extremely hot and dry during the drier months. One way which reptiles deal with this, is to alter their activity patterns and behaviour (pers. obs.). The other appears to be by selecting plant and invertebrate foods which have high water content. Obtaining sufficient water is imperative to maintain metabolic processes and ultimately for survival. Other animals are known to do the same (Combreau & Smith 1997; Lagarde *et al*. 2003).

Overall the low selectivity of invertebrates is probably due to their high abundance, as invertebrates were frequent and abundant in the faecal samples. Therefore, the reptiles did not apply selective predation pressures on them. The studied species have an ample food supply and probably select prey that provide the most energy, and are easier to capture and consume. Food is unlikely to be a stress factor. Calculating electivity indices of translocated reptiles would be valuable for comparative reasons and to assess whether similar prey items are chosen based on ease of capture and energetic content.

Dietary overlap and temporal variation

The change in dietary diversity and overlap of the Round Island reptiles may be explained by opportunistic foraging, that is, being relatively non-selective and eating food items in relation to their abundance or availability in the environment. When only a few food types are available, such as during the dry months, lizards utilise these and hence have higher dietary overlap and lower dietary diversity than during periods of high food item abundance. During the wetter periods, more food types are available and the abundance of most food items increases. Foraging differed between habitats; consequently, dietary overlap could be low and dietary diversity higher, as a result of differences in microhabitat use by the different Round Island reptiles.

Reptiles similar in body size, microhabitat use and food choice are more likely to compete for resources, if limited (Pianka 1973). There are two groups with high overlap in many niche dimensions, like diet, substrate used and foraging mode. One the Telfair's skink, Bojer's skink and Durrells' night gecko, and the other, the Ornate day gecko and Guenther's gecko.(Lack 1946) hypothesized that during periods of low food availability, food choice overlap should be lower as species specialise on different food resources to reduce competitive interactions. In the Round Island reptile assemblage, the opposite trend was observed: dietary overlap between most groups of species was higher during drier months, when food item availability was lower and lowest during wet months when food availability was high. Our result does not contradict Lack's hypothesis, but may merely indicate that at no time were the species competing for food. An increase in dietary overlap during dry months suggests that the species may be competing more strongly for food and that convergence on invertebrate food may work against a diverse diet. However, the Round Island reptiles partition the invertebrate prey such that each species of lizard harvested different type of invertebrates. The lack of consistent patterns of food item utilisation within and between species, suggests that there may have been negligible intraspecific and interspecific competitive interactions in terms of diet in the Round Island reptile assemblage.

We found that predator weight determined dietary overlap, with ontogenetic shifts often outweighing taxonomic differences. Species with similar weight have similar diets. Small predators had the narrowest diets, regardless of species, and were limited to feeding on a restricted subset of the total prey size-spectrum, with the exception of the boa. Overlap in diet also tracked seasonal changes in resource availability, being lowest in the wet months, when food items were abundant and progressively increasing with time in the dry months as

food items became scarcer. The Round island reptile assemblage, thus, partially contradicts Pianka's (1973) and Woodward's (2002) findings.

In conclusion, the Round Island lizards share many food resources; however, their preferred food items differed to some extent. The Telfair's skink was the most omnivorous. All the lizards consumed invertebrates. There was large overlap in the diets of the Telfair's skink, Bojer's skink and Durrells' night gecko, and the Ornate day gecko and Guenther's gecko. If food is limited, competition is predicted. The large numbers of each species (see chapter 2) suggests that competition does not limit populations and that food resources are not a limiting factor.

The Round Island invertebrate fauna is poorly known, but undoubtedly diverse and abundant (Bullock 1986; North *et al*. 1994); We found 419 invertebrate morpho-species. Invertebrate availability differed with microsite and at different times of the day (pers obs.). This will influence the lizard's foraging opportunities and the densities in which the different species can be found in each of the seven habitat types.

We have shown that sympatric tropical reptiles coexisting on an oceanic island off the north-east coast of Mauritius are selective, feeding on different sets of food items. Furthermore, adult and juvenile reptiles of all the species fed on different sets of food items. In addition, dietary overlaps were generally low but increase depending on the time of year and food abundance. Some species have generalised diets, feeding on a variety of foods, while others were specialists. Much of the variation in food choice appears related to lizard body size and weight. Similar relationships occur in other tropical lizard studies (Vitt & Zani 1996, 1998).

From a conservation aspect and regarding translocation, since invertebrates are the most important diet constituent of adult and juvenile Round Island lizards, we recommend that recipient sites should have a rich invertebrate fauna. Since juvenile and adult conspecifics do not compete for the same food resources, both ages could be translocated at the same time. Nevertheless, it would be better to translocate larger individuals of a species, as they are less restrictive in diet choice and so can adjust their diet to consume the new food items in their environment. Consequently, survival chances are likely to be greater.

We recommend translocating omnivores, prior to specialist species. If the recipient site has an abundant food supply, then several species at a time could be translocated, even if their dietary niches' overlap as competition for food resources did not occur. Since the Keel-scaled boa was the top predator their translocation should not be considered until there is a well establish and abundant reptile and bird population. Based on our findings, we believe

that if a recipient site were to have a replicated Round Island herpetofauna established, then the small reptile species should be translocated first, allowed to establish viable populations, and then larger ones can be introduced. Regardless, the recipient site's species should be carefully considered as assumed impacts are not necessarily predictable. For example, we have found that the three largest reptiles have high electivity indices for land birds. Careful evaluation should be taken prior to their translocation to areas with endangered land birds.

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Appendix I. Summary of the GLMs determining if there was a difference in the food items chosen by the seven Round Island reptile species for the 12 different months of the study period (Monthly variation in the table) and if diet varied for adults and juveniles of each species (Age difference in the table). Table (a) show the results when the food items were not grouped and table (b) when the items were grouped. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold.

Table (a)

Status	Age	Monthly variation			Age difference		
		d.f.	*F*	*P*	d.f.	*F*	*P*
Telfair's skink	Adult	11,1023	7.39	**<0.0001**	1,2161	42.69	**<0.0001**
Telfair's skink	Juvenile	11,1023	21.88	**<0.0001**			
Bojer's skink	Adult	11,1023	27.85	**<0.0001**	1,2161	110.29	**<0.0001**
Bojer's skink	Juvenile	11,1023	89.15	**<0.0001**			
Bouton's skink	Adult	11,1023	27.25	**<0.0001**	1,2161	538.37	**<0.0001**
Bouton's skink	Juvenile	11,1023	65.52	**<0.0001**			
Ornate day gecko	Adult	11,1023	16.77	**<0.0001**	1,2161	381.31	**<0.0001**
Ornate day gecko	Juvenile	11,1023	28.47	**<0.0001**			
Guenther's gecko	Adult	11,1023	24.57	**<0.0001**	1,2161	274.81	**<0.0001**
Guenther's gecko	Juvenile	11,1023	49.75	**<0.0001**			
Durrells' night gecko	Adult	11,1023	57.83	**<0.0001**	1,2161	441.37	**<0.0001**
Durrells' night gecko	Juvenile	11,1023	75.11	**<0.0001**			
Keel-scaled boa	Adult	11,1023	21.16	**<0.0001**	1,2161	134.94	**<0.0001**
Keel-scaled boa	Juvenile	11,1023	82.09	**<0.0001**			

Table (b)

Status	Age	Monthly variation			Age difference		
		d.f.	*F*	*P*	d.f.	*F*	*P*
Telfair's skink	Adult	11,33	0.005	1	1,94	0.008	1
Telfair's skink	Juvenile	8,36	0.004	1			
Bojer's skink	Adult	8,36	0.006	1	1,94	0.002	1
Bojer's skink	Juvenile	8,36	0	1			
Bouton's skink	Adult	8,36	0	1	1,94	2.4	0.12
Bouton's skink	Juvenile	8,36	1.9	0.088			
Ornate day gecko	Adult	8,36	0	1	1,94	0	1
Ornate day gecko	Juvenile	8,36	0	1			
Guenther's gecko	Adult	8,36	0.001	1	1,94	0.007	0.79
Guenther's gecko	Juvenile	8,36	0.24	0.979			
Durrells' night gecko	Adult	8,36	0	1	1,94	0.23	0.63
Durrells' night gecko	Juvenile	8,36	0.49	0.858			
Keel-scaled boa	Adult	8,36	0	1	1,94	0	1
Keel-scaled boa	Juvenile	8,36	0	1			

Appendix II. The number of different food items consumed by the Round Island reptiles per month over a period of one year. In table (a), invertebrates are identified to morpho-species whereas in table (b) they grouped to order.

Table (a)

	Telfair's skink		Bojer's skink		Bouton's skink		Ornate day gecko		Guenther's gecko		Durrells' night gecko		Keel-scaled Boa	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
January	61	68	69	46	5	0	48	23	22	11	52	2	6	3
February	72	73	58	27	16	6	43	25	27	25	38	7	5	3
March	89	71	62	33	21	8	46	38	37	30	50	8	6	7
April	81	92	62	23	4	0	50	30	40	32	48	15	5	4
May	75	68	57	23	15	7	44	25	30	28	39	0	7	4
June	86	75	69	21	24	0	51	39	39	13	48	8	6	3
July	56	39	35	25	11	6	31	7	2	0	16	0	4	1
August	56	53	46	25	17	12	38	16	20	21	21	4	3	2
September	63	63	56	44	35	12	45	34	11	12	35	13	4	2
October	55	66	63	49	19	0	40	42	22	8	41	12	4	4
November	63	68	56	54	16	0	46	41	29	34	40	20	5	4
December	57	65	66	48	12	0	39	41	28	17	40	7	5	3
Mean ±SD	68 ±12	67 ±13	58 ±10	35 ±12	16 ±8	9 ±5	43 ±6	30 ±11	26 ±11	21 ±11	39 ±11	10 ±6	5 ±1	3 ±1

Table (b)

	Telfair's skink		Bojer's skink		Bouton's skink		Ornate day gecko		Guenther's gecko		Durrells' night gecko		Keel-scaled Boa	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
January	25	21	18	13	2	0	13	8	10	6	15	1	6	3
February	26	22	14	10	8	3	12	11	10	9	13	3	5	3
March	27	21	16	8	9	4	10	10	14	9	14	4	6	7
April	26	21	17	9	2	0	13	10	16	11	13	6	5	4
May	25	19	16	9	7	3	12	9	10	9	11	0	7	4
June	28	18	16	3	10	0	13	11	14	6	12	3	6	3
July	21	14	10	8	5	3	11	3	2	0	6	0	4	1
August	22	15	14	9	8	5	9	5	11	7	7	2	3	2
September	30	17	14	11	14	6	11	11	6	5	10	6	4	2
October	25	19	18	13	9	0	11	9	10	2	12	5	4	4
November	28	19	15	13	6	0	11	10	11	12	10	6	5	4
December	28	19	18	13	6	0	12	13	8	8	10	3	5	3
Mean ±SD	26 ±3	19 ±2	16 ±2	10 ±3	7 ±3	4 ±2	12 ±1	9 ±3	10 ±4	8 ±3	11 ±3	4 ±2	5 ±1	3 ±1

Appendix III. Electivity values for the different food items selected by the seven Round Island reptile species at the adult and juvenile stage over a period of one year. Values were calculated using Vanderploeg & Scavia's relativised electivity index (Lechowicz, 1982; Vanderploeg & Scavia, 19799 Electivity index values close to +1 indicates active selection, close to -1 indicates avoidance of prey items and values close to 0 show random selection.

	Telfair's skink		Bojer's skink		Bouton's skink		Ornate day gecko		Guenther's gecko		Durrells' night gecko		Keel-scaled Boa	
	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Abutilon indicum flower	-0.056	-0.628	-0.448	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Abutilon indicum fruit	-0.990	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Commelina benghalensis flower	-0.991	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Dracean concinna fruit	-0.902	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Ehretia petiolaris fruit	-0.277	-0.643	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Hyophorbe lagenicaulis nectar	-1	-1	-1	-1	-1	-1	-0.655	-1	-1	-1	-1	-1	-1	-1
Ipomea pres-caprea flower	-0.927	-0.987	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Latania lodigesii flower	-1	-1	-0.237	-1	-1	-1	0.864	0.845	0.391	0.838	-1	-1	-1	-1
Latania lodigesii fruit	0.583	0.644	-0.237	-1	-1	-1	-0.655	-1	-0.628	-1	0.011	-1	-1	-1
Latania lodigesii nectar	-0.808	-0.941	-1	-1	-1	-1	-0.871	-1	-1	-1	-1	-1	-1	-1
Lomatophylum tormentorii nectar	0.588	0.730	-1	-1	-1	-1	0.333	0.176	-1	-1	-1	-1	-1	-1
Lomatophylum tormentorii fruit	-0.303	0.127	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Myoporum mauritianum fruit	-0.929	-0.969	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Pandanus vandermeerschii flower	-0.898	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Pandanus vandermeerschii fruit	-0.822	-0.970	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Passiflora suberosa fruit	-0.996	-0.975	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Passiflora suberosa flower	-0.886	-0.894	-0.899	-0.953	-1	-1	-1	-1	-0.995	-1	-1	-1	-1	-1
Premna serratifolia fruit	-0.926	-0.948	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Scavola taccada fruit	-0.989	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Scavola taccada flower	-0.920	-0.986	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Solanum nigrum flower	-0.988	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Solanum nigrum fruit	-0.960	-0.975	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Blattodea	-0.862	-0.753	-0.281	-0.396	-0.953	-0.840	-0.965	-0.969	-0.962	-0.763	-0.417	-0.598	-1	-1
Centipede	-0.621	-1	-0.194	-1	-1	-1	-1	-1	-0.846	-1	0.056	-1	-1	-1
Coleoptera Adult	-0.583	-0.154	0.000	-0.020	-0.912	-1	-0.532	-0.583	-0.814	-0.013	-0.557	-0.767	-1	-1
Coleoptera Grubs	-0.294	-0.522	0.760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Collembolla	-1	-0.971	-0.968	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Crabs	-0.955	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Dermaptera	-0.567	-0.249	-0.331	-0.308	-1	-1	-0.796	-0.805	-0.921	0.137	-0.090	0.397	-1	-1
Diptera	-0.991	-0.933	-0.813	-0.863	-0.722	-0.840	-0.872	-0.842	-0.998	-0.966	-0.819	-1	-1	-1
Earthworm	-1	-0.400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Embioptera	-0.616	-0.318	0.268	-0.021	-0.048	-0.240	-0.529	-0.762	-0.917	-0.531	0.629	0.561	-1	-1
Hemiptera heteroptera	-0.456	0.226	-0.071	0.022	-0.858	-1	-0.948	-0.980	-0.992	-0.847	-0.769	-1	-1	-1
Hemiptera homoptera	-0.985	-0.895	-0.649	-0.790	-0.937	-1	-0.938	-0.962	-0.993	-0.899	-0.688	-1	-1	-1
Hymenoptera Ants	-0.997	-0.990	-0.976	-0.973	-0.993	-0.993	-0.995	-0.996	-0.999	-0.996	-0.982	-0.989	-1	-1
Hymenoptera wasps	-0.601	0.248	0.690	0.725	0.308	0.436	0.177	0.086	-0.942	-0.057	0.643	0.337	-1	-1
Lepidoptera adult	-0.968	-0.847	-0.417	-0.383	-0.790	-0.886	-0.874	-0.877	-0.985	-0.844	-0.446	-0.658	-1	-1
Lepidoptera caterpillars	-0.787	-0.279	0.493	0.464	-0.499	-0.470	-0.777	-0.868	-0.990	-0.644	0.024	-0.273	-1	-1
Orthoptera	-0.829	-0.639	-0.246	-0.319	-0.024	-0.400	-0.527	-0.408	-0.919	-0.538	-0.137	-1	-1	-1
Pseudoscorpions	-1	-0.893	0.061	-0.255	0.783	0.663	-1	-1	-1	-1	-1	-1	-1	-1
Scorpions	-0.958	-0.985	-1	-1	-0.786	-0.216	-1	-1	-0.885	-0.512	-1	-1	-1	-1
Snails	-0.956	-0.813	-0.951	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Spiders	-0.937	-0.713	-0.113	0.098	-0.438	-0.385	-0.668	-0.661	-0.955	-0.538	-0.037	-0.261	-1	-1
Thysanura	-0.986	-0.942	-0.449	-0.330	0.381	0.447	-1	-1	-0.995	-1	-0.502	-1	-1	-1
Woodlice	-0.966	-0.883	-0.693	-0.290	-0.360	-0.710	-0.814	-0.832	-0.992	-0.873	-0.359	-0.473	-1	-1
Zebra ground barred dove Adult	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0.414	-1
Zebra ground barred dove Chicks	0.653	-1	-1	-1	-1	-1	-1	-1	0.862	-1	-1	-1	0.654	-1
Zebra ground barred dove Eggs	0.949	0.920	-1	-1	-1	-1	-1	-1	0.816	-1	-1	-1	-1	-1
White-tail tropicbird Chicks	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.192	-1
White-tail tropicbird Eggs	-0.132	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Red-tail tropicbird Eggs	-0.794	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Round Island petrel Eggs	0.129	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Wedge-tailed shearwater Chicks	-0.565	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.283	-1
Wedge-tailed shearwater Eggs	0.462	0.087	0.261	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Calamary and fish bits	-0.223	0.136	-0.154	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Keel-scaled Boa Juvenile	-0.700	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Bouton's skink Adult	-0.764	-0.368	-0.129	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.763	-1
Bouton's skink Juvenile	-1	-0.089	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Bojer's skink Adult	-0.863	-0.962	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.889	-0.994
Bojer's skink Juvenile	-0.783	-0.283	0.077	-1	-1	-1	-1	-1	-0.944	-0.241	-1	-1	-1	-0.235
Telfair's skink Adult	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.209	-1
Telfair's skink Juvenile	-0.316	-0.668	-1	-1	-1	-1	-1	-1	-0.921	-1	-1	-1	-0.840	-0.342
Durrells' night gecko Adult	-0.954	-1	-1	-1	-1	-1	-1	-1	-0.617	-1	-1	-1	-0.048	-0.610
Durrells' night gecko Juvenile	-1	-1	-1	-1	-1	-1	-1	-1	-0.601	-1	-1	-1	-1	0.496
Guenther's gecko Adult	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.153	-1
Guenther's gecko Juvenile	-0.637	-0.133	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.198	-1
Ornate day gecko Adult	-0.931	-1	-1	-1	-1	-1	-1	-1	-0.505	-1	-1	-1	-0.514	-0.834
Ornate day gecko Juvenile	-0.797	-0.441	-1	-1	-1	-1	-0.206	-1	-0.162	-1	-1	-1	-1	0.442

Appendix IV. Diet overlap (calculated as Pianka's niche overlap) between the seven reptile species of Round Island at the adult and juvenile stages over a period of one year. Index values close to 1 indicate high overlap and values close to 0 show no overlap.

Species		Telfair's skink		Bojer's skink		Bouton's skink		Ornate day gecko		Guenther's gecko		Durrells' night gecko		Keel-scaled Boa	
	Age	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Telfair's skink	Adult		0.941	0.845	0.799	0.526	0.587	0.722	0.677	0.871	0.812	0.755	0.743	0.012	0.010
	Juvenile			0.889	0.880	0.630	0.647	0.830	0.788	0.829	0.820	0.801	0.772	0.001	0.006
Bojer's skink	Adult				0.980	0.720	0.735	0.859	0.838	0.845	0.862	0.948	0.910	0	0.003
	Juvenile					0.780	0.777	0.908	0.893	0.814	0.857	0.947	0.912	0	0
Bouton's skink	Adult						0.924	0.804	0.819	0.566	0.620	0.784	0.740	0	0
	Juvenile							0.747	0.742	0.615	0.634	0.759	0.730	0	0
Ornate day gecko	Adult								0.988	0.793	0.828	0.867	0.826	0	0.005
	Juvenile									0.778	0.829	0.855	0.801	0	0
Guenther's gecko	Adult										0.960	0.795	0.773	0.025	0.054
	Juvenile											0.824	0.790	0	0.006
Durrells' night gecko	Adult												0.983	0	0
	Juvenile													0	0
Keel-scaled Boa	Adult														0.076
	Juvenile														

CHAPTER 4

Gut passage through the Telfair's skink increases the germination success of endemic but decreases the survivorship of exotic plant species

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Gut passage through the Telfair's skink increases the germination success of endemic but decreases the survivorship of exotic plant species

Abstract

On many islands lacking mammalian guilds, reptiles often fulfill key ecosystem functions, such as seed dispersal. With the arrival of humans to these islands, there followed the introduction of exotic species which were generally more competitive than the native ones. In two experiments, we investigated the effects of ingestion by the Telfair's skinks, *Leiolopisma telfairii*, on seed germination time, germination success and seedling survivorship of three endemic, four native and two exotic fleshy-fruit species on Round Island. Fruit traits, gut passage and depulping of the fruit effected the germination time and success and survivorship. We found that the germination success of endemic species increased, while the survivorship of the exotic species decreased following gut passage and the subsequent deposition in faeces. These results were consistent over the two experiments and persisted even after accounting for differences in morphological fruit and seed characteristics among the endemic and exotic species. Contrary to expectation, our results suggest that the translocation of the Telfair's skinks to new islands will be beneficial to restoration efforts by reducing the seedling survivorship of exotic fleshy-fruit species. Further investigation of plant-animal interactions for seed dispersers, such as the Telfair's skinks, should be considered prior to translocation.

Introduction

Vertebrates play an important role as pollinators and seed dispersers (Van der Pijl 1982). Dispersed seeds often survive better further from the parent plant (Connell 1971; Hulme 1998; Janzen 1970). To entice vertebrates to consume and disperse their seeds, some plants have evolved a fleshy, nutritious pulp and morphological fruit characteristics (Howe & Smallwood 1982; Olesen & Valido 2003). Birds and mammals are reportedly the most widespread vertebrate dispersers (Janzen 1983). Consequently, dispersal syndromes, certain fruit morphologies and traits, such as shape, colour and smell, have been identified for these frugivores (Van der Pijl 1982). However, the importance of lizards as seed dispersers has often been underestimated, especially in island ecosystems (Olesen & Valido 2003; Valido &

Olesen 2007). As a result, no general lizard syndrome has been described. This is because lizards are generally considered to be mainly carnivorous, with only 1% classified as truly herbivorous (Cooper & Vitt 2002). Nevertheless, many lizards consume a broad diet, including flowers, fruit, nectar and pollen (Cooper & Vitt 2002).

Some frugivorous reptiles are poor seed dispersers as they destroy the seeds while consuming them (Van der Pijl 1982). However, others reptiles are important seed dispersers as many seeds remain viable and experience increase in germination rate after gut passage (Braun & Brooks 1987; Rick & Bowman 1961; Traveset 1998). This can be due to various reasons, such as the softening of the seed coat, provision of a moist microsite and/or the addition of nutrients from the faeces (Grice 1996).

Islands have high levels of endemism but their communities are often disharmonious compared to continental areas. This is due to long distance isolation from nearby large land masses and the poor ability of many species to disperse over water (Cheke & Hume 2008; MacArthur & Wilson 1967; Whittaker & Fernandez-Palacios 2007). For example, with the exception of bats, mammals failed to colonise Mauritius on their own (Cheke & Hume 2008). Here, birds and reptiles often perform the key ecosystem functions, such as grazing, pollination and seed dispersal (Cheke & Hume 2008). Since a large proportion of the pristine endemic Mauritian fauna was comprised of lizards (Cheke & Hume 2008), they undoubtedly had a major impact on the ecosystem. Despite the lack of historical records of lizards feeding on Mauritian fruits or seeds, it is believed that they were important seed dispersers (Hansen & Müller in press; Vinson & Vinson 1969). For example, the omnivorous Telfair's skink readily feeds on both native and exotic fruits on Round Island, Mauritius (Jones 1993; Pernetta *et al*. 2005; Vinson 1975) (see chapter 3).

As part of ongoing conservation measures, in February 2007 250 Telfair's skinks (*Leiolopisma telfairii*) were relocated to Gunner's Quoin and 190 to Ile aux Aigrettes, to establish additional populations and hence reduce the risk of extinction (Cole *et al*. 2007). One of the fears associated with this relocation was that the Telfair's skinks would accelerate the spread of alien plant species, thereby having a detrimental impact on the restoration efforts of these recipient sites (Pernetta *et al*. 2005). However, how seed germination of exotic plant species compared to native plant species is affected by reptile's gut passage remains unexplored (Bartuszevige & Gorchov 2006; Vila & D'Antonio 1998).

This study investigated whether gut passage through the Telfair's skink had a differential effect on the germination rate, germination success and survivorship of seedlings for endemic, native and exotic species common to Round Island. Studies of the germination

capacity of seeds after gut passage have received relatively little attention, especially for reptiles, and most notably lizards (Traveset 1998). Furthermore, we compare whether the effect of gut passage on seed germination differs between seeds from endemic, native and exotic plants. Our findings provide valuable insights on seed germination and the role of reptiles in ecosystem functioning. Furthermore, our results provide important insights on the role of reptiles on seed germination and seedling survivorship, which may be crucial factors ultimately determining the composition of plant communities (Traveset 1998). These data will help guide the restoration of plant and reptile communities.

Materials and methods

Study site

The study was conducted on Round Island (57°47□03□E, 19°54□03□S), the remains of a basaltic volcanic cone, located 22.4 km off the north coast of Mauritius (Merton *et al*. 1989). This 219 ha island rises 280 m above sea level (Johansson 2003). The germination experiment was conducted in the plant propagation nursery.

Study species

The Round Island skink or Telfair's skink, *Leiolopisma telfairii* (Desjardin, 1831), is the largest extant Mauritian skink (Jones 1993), reaching a total maximum length of between 30 to 40 cm. The species was once widespread on the main island of Mauritius, as sub fossil remains were found at Le Pouce in the north, the lowland Black River gorges in the west and Mare aux Songes in the southeast of the island (Arnold 1980; Cheke & Hume 2008). Preliminary feeding observations and faecal analyses indicate that they are omnivorous (Bullock 1986; Jones 1993; Pernetta *et al*. 2005; Vinson & Vinson 1969); see chapter3).

We used fleshy fruits, with the exception of *Pandanus vandermeeschii*, found in the diet of the Telfair's skinks on Round Island (see chapter 3). Despite its dissimilarity in fruit traits, *Pandanus vandermeerschii* was used, as skinks actively sought this endemic fruit, which is an important component of Round Island's palm forest. There were three endemics (*Lomatophyllum tormentorii, Myoporum mauritianum* and *Pandanus vandermeerschii*), four natives (*Dracaena concinna, Hilsenbergia* petiolaris, *Premna serratifolia* and *Scaevola taccada*) and two exotic species (*Passiflora suberosa and Solanum nigrum*). Fruit and seed characteristics of the study species are listed in Table 1.

Lomatophyllum tormentorii is a succulent shrub; its fleshy leaves are simple, alternate and usually crowded at the base of the stem. The Inflorescence are terminal with reddish-yellow flowers (Rouillard & Guého 1999). It naturally occurs on the summit and in the crater, but has since been planted in the south of the island.

Myoporum mauritianum is a shrubby plant, with woody stems whose leaves are alternate, hairy and serrated. Its inflorescences are terminal and axillary, with white small flowers (Rouillard & Guého 1999). This plant was introduced to Round Island and mainly occurs in the restoration planting sites.

Pandanus vandermeerschii is a medium-sized tree with a broad canopy. The trunk is stout, wide-branching, and ringed with many leaf scars. The leaves are strap-shaped. *P. vandermeeschii* is dioecious, the flowers of the male tree are long and fragrant and the female tree produces flowers with round fruits, which are globose, and have many prism-like sections (Rouillard & Guého 1999). They occur along a belt around the summit, in the crater and in the palm forest.

Dracaena concinna is a treelike, shrubby plant, with simple or branched, woody stems. Its leaves are crowded toward the apex of stems and the leaf blade usually sword-shaped, with veins running parallel from base. Inflorescences are terminal with yellow flowers (Rouillard & Guého 1999). This plant was introduced in 1991 (Strahm 1993) and occurs mainly in a belt around the summit and in the restoration planting sites.

Hilsenbergia petiolaris is a tree whose leaves are simple, alternate and entire. Inflorescences are composed of small white flowers (Rouillard & Guého 1999). This plant native to Mauritius, Réunion and Madagascar was introduced to Round Island and mainly occurs in the restoration planting sites.

Premna serratifolia is a treelike, shrubby plant whose leaves are simple and opposite. The Inflorescence is terminal with aggregated small white flowers. It is native to the Mascaregnes (Rouillard & Guého 1999). This plant was introduced to Round Island and mainly occurs in the restoration planting sites.

Scaevola taccada is a shrubby plant, with alternate leaves and white flowers (Rouillard & Guého 1999) It was introduced to Round Island and occurs mainly in the restoration planting sites.

Passiflora suberosa is a woody perennial vine, with simple and alternate leaves. Inflorescence is axillary with white large flowers. This exotic species has a south-American origin and was introduced to Mauritius in the 1830s (Rouillard & Guého 1999). It was

introduced to Round Island in the early 1990 (Strahm 1993) and is now ubiquitous on the island.

Solanum nigrum is a shrubby plant, with hairy stems and alternate leaves. Inflorescence is terminal and axillary, with white small flowers. This exotic species has a Brazilian origin and was introduced to Mauritius in the 1630s (Rouillard & Guého 1999).It was introduced to Round Island in the mid 1990 (Strahm 1993) and is now ubiquitous on the island.

Table 1. Fruit species used in the seed germination experiment and their characteristics. Mean obtained from 30 fruits and seeds.

Scientific name	Family	Status	Fruit colour when ripe	Mean fruit size/ mm	Mean seed size/ mm	Mean number of seeds per fruit
Lomatophyllum tormentorii	Liliaceae	Endemic	Yellowish-red	12.5 ±1.7	2.2 ±0.2	15 ±13
Myoporum mauritianum	Myoporaceae	Endemic	Violet-pink	5.2 ±1.1	4.1 ±0.4	1 ±0
Pandanus vandermeerschii	Pandanaceae	Endemic	Green, yellow and red	41.2 ±9.2	41.2 ±9.2	1 ±0
Dracaena concinna	Dracaenaceae	Native	Bright orange	14.3 ±1.9	9.8 ±0.4	2 ±0
Hilsenbergia petiolaris	Boraginaceae	Native	Bright red	5.0 ±0.9	3.2 ±0.3	4 ±0
Premna serratifolia	Verbenaceae	Native	Black	4.2 ±1.1	2.9 ±1.1	1 ±0
Scaevola taccada	Goodeniaceae	Native	White	12.3 ±2.6	7.4 ±1.1	1 ±0
Passiflora suberosa	Passifloraceae	Exotic	Dark purple	11.3 ±2.4	4.1 ±0.3	12 ±11
Solanum nigrum	Solanaceae	Exotic	Dark purple	5.6 ±1.6	1.1 ±0.2	55 ±26

Experimental set up

The experiment was conducted from January to September 2008. Fresh fruits were collected from 6-14 plants, depending on fruit set. Only freshly collected fruits were used in the experiment to keep the degree of germinability constant. Here after, seeds refer to manually depulped seeds, i.e. the fleshy pulp has been removed from the seed. With the exception of *Pandanus vandermeershii* which lacks a fleshy epicarp, each species was tested for the six treatments listed in Table 2

Table 2. The treatments used in the experiment. For *Pandanus vandermeerschii*, there were only three treatments as the seed lacks a fleshy epicarp.

Treatment		
Substrate	**Gut passage**	**Propagule type**
With faeces	Gut passage	Seeds
	Gut passage	Fruits
Without faeces	Gut passage	Seeds
	Gut passage	Fruits
	No gut passage	Seeds
	No gut passage	Fruits

Fruits and seeds were planted in compartmentalised seedling trays (plug trays) as controls (without faeces, no gut passage). Fruits and seeds were also force-fed to fifteen Telfair's skinks each, which were subsequently kept in plastic containers for four days to collect the faecal matter. The same-treatment faeces were mixed to provide a homogenised sample and avoid individual skink effects. To test the effect of faeces on the germination time, success and survival of seedlings, the faeces were divided into two groups; one in which faeces were removed from the seeds for the "without faeces" treatment, and the other in which the faeces were left for the "with faeces" treatment (Table 2).

Thirty replicates per treatment were randomly placed in a block design in three plug trays for each species. Each tray held 77 replicates. The numbers of fruits/seeds per replicate was based on the mean number of seeds of each species found in the faeces of the Telfair's skinks caught on Round Island in another study (see chapter 3); thus emulating the density in which seeds of a particular species are typically defecated. The amount of soil was kept constant. Treatments were sown in a depth of 1 cm soil. Trays were rotated weekly to avoid microclimate effects that could influence germination and growth. Trays were checked daily, watered when necessary, and any germination and seedling death recorded. Germination was defined as the emergence of the epicotyl, and germination time as the time taken for a seed to germinate from the moment it was sown. After four months an experiment was terminated, and the total number of surviving seedlings recorded.

Table 3. The number of fruits and seeds used in each replicate for each species. The number of seeds was based on the mean number of seeds per fruit (Table 1).

Scientific name	Number of fruits	Number of seeds
Dracaena concinna	2	4
Hilsenbergia petiolaris	4	16
Lomatophyllum tormentorii	2	15
Myoporum mauritianum	4	4
Pandanus vandermeeschii	-	3
Passiflora suberosa	4	50
Premna serratifolia	4	4
Scaevola taccada	4	4
Solanum nigrum	4	200

Statistical analyses

Data were analysed by fitting generalised linear models (GLMs), using the software package R.2.7.0 (R Development Core Team 2008). Generalised linear models with status (endemic, native, exotic), species and ingestion (ingested by Telfair's skink and germinated in their droppings vs. not ingested/without dropping matter) as treatment factors and tray identity as a blocking factor were fitted to determine which of the aforementioned factors effected

germination time, percentage germination and survivorship. Quasi-Poisson errors distribution was used for the germination time, and Binomial error distribution for the germination percentage and survivorship. As tray identity had no significant effect on any of the response variables, it was removed from the models before further analyses. To account for statistical overdispersion, mean deviance changes were compared with *F*-tests (Crawley 2005).

To further investigate which factors were responsible for the overall effect of Telfair's skink ingestion, we fitted GLMs with propagule (fruits manually depulped or not depulped), gut passage (gut-passed or not gut-passed) and faeces (with or without) as treatment factors, status, species, fruit size, seed size and seed density as covariables and tray identity as a blocking factor to explain variation in germination time, percentage germination and percentage survivorship. Again, tray identity had no significant effect on any of the response variables tested and was removed from the models. Since we were particularly interested in differential effects for species of the three different status groups, and status was significant in the model including all species, separate models for each status group were fitted with species as the only co-variable.

Results

Effect of ingestion on seedlings germination time, percentage germination and survivorship

For non-ingested fruits, percentage germination ($F_{2,267}$= 5.19, P=0.006) and germination time ($F_{2,121}$= 24.13, P<0.0001) differed significantly between exotic, native and endemic species, with exotic species germinating at higher percentages and quicker than native or endemics ones (Fig. 1 & Appendix I). Species identity explained additional variance (germination time: $F_{6,115}$= 43.73, P<0.0001; percentage germination: $F_{6,261}$= 3.81, P<0.0001) (Fig. 1 & Appendix I). In contrast, the endemic species showed a higher survivorship than the native or exotic species ($F_{2,123}$= 6.54, P=0.001). Species identity explained additional variation ($F_{6,117}$= 4.18, P<0.0001) (Fig. 1 & Appendix I).

Ingestion by Telfair's skink had a marginally significantly ($F_{1,70}$= 2.99, P=0.088) reduced germination time for endemic species, whereas for native and exotic species no significant effect was found (Fig 1 & Appendix II). Percentage germination of ingested fruits, however, was significantly increased ($F_{1,178}$= 9.49, P=0.002) compared to not ingested fruits in endemic species, but not in native or exotic species (Fig 1 & Appendix II). Percentage survivorship of ingested fruits was slightly but statistically not significantly increased compared to not ingested fruits in endemic and native species (Fig 1 & Appendix II). In

contrast, there was a statistically significant decrease in the survivorship in exotic species ($F_{1,91}$= 2.39, P=0.007) (Fig 1 & Appendix II).

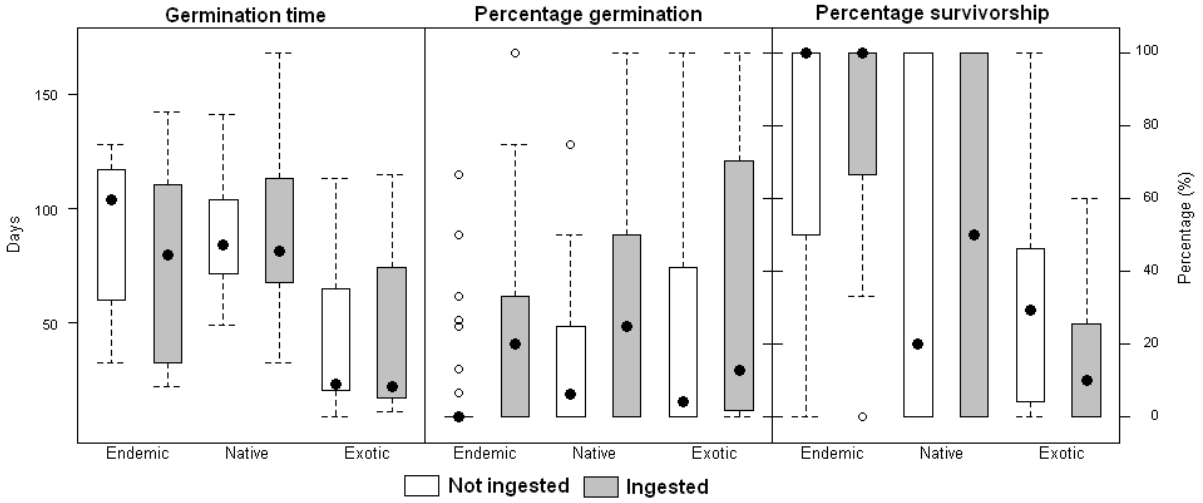

Figure 1. Comparisons of the effect of gut passage on the germination time, percentage germination and percentage survivorship of endemic, native and exotic Round Island fruits, ingested or not ingested by Telfair's skinks. The mean is indicated by a solid dot, the standard deviation by the bars, interquartile range by the enclosed rectangle and outliers by open circles.

The effect of skink ingestion varied not only among plant species of different status, but also among species within a status group (Fig. 2-4 & Appendix III). However, the significant decrease in survivorship found for the exotics was consistent for both plant species of this group (Fig. 4). Germination time significantly decreased for ingested fruits compared to not ingested fruits in some species, *Lomatophyllum tormentorii, Hilsenbergia petiolaris*, *Premna serratifolia* and *Solanum nigrum* (Fig. 2 & Table 5 & 6 & Appendix III).

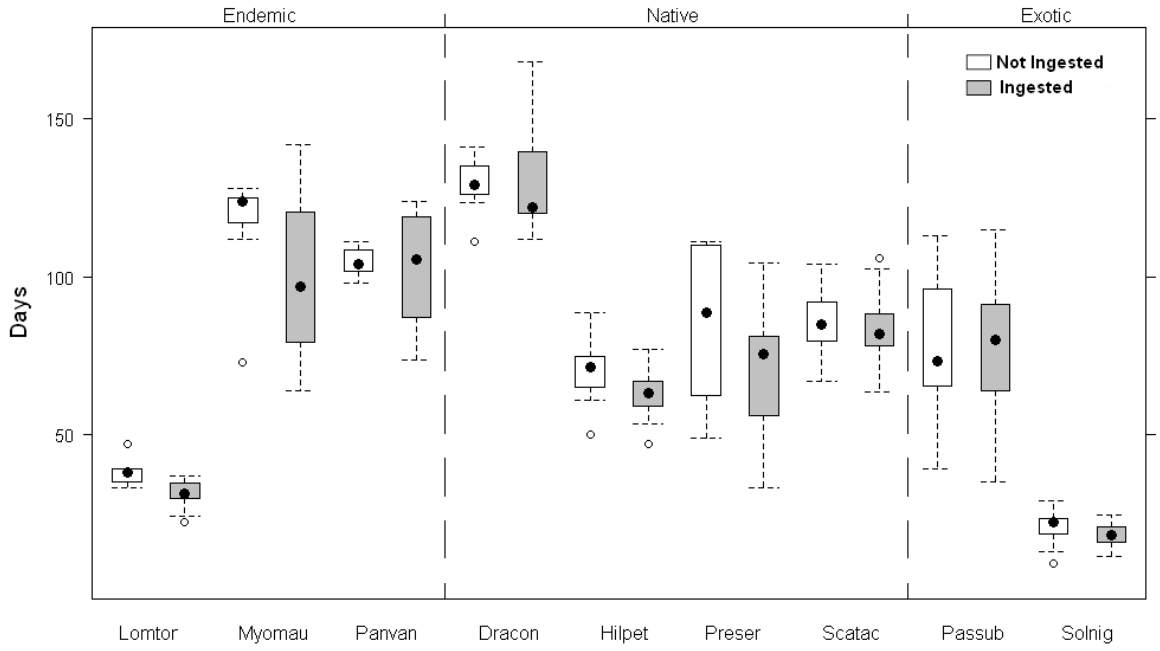

Figure 2. Comparisons of the effect of ingestion by Telfair's skink on the germination time of native, endemic and exotic Round Island fruits. The mean is indicated by a solid dot, the interquartile range by the rectangle, the standard deviation by bars and outliers by open circles. Lomtor= *Lomatophyllum tormentorii,* Myomau=

Myoporum mauritianum, Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*.

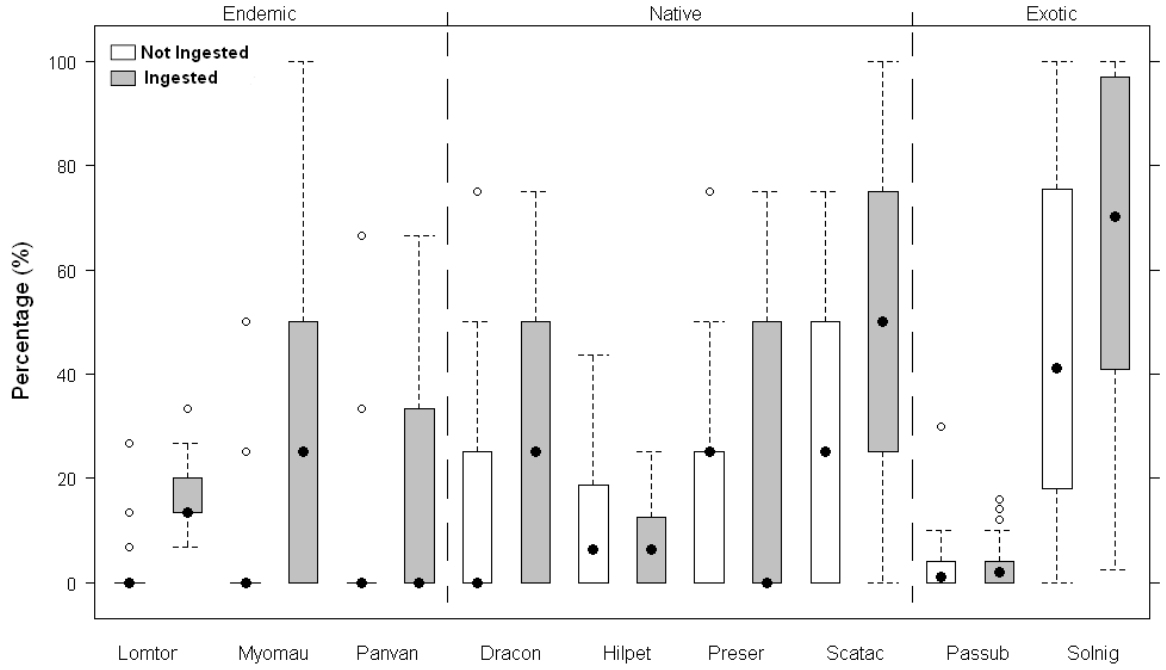

Figure 3. Comparisons of the effect of ingestion by Telfair's skink on the percentage germination of native, endemic and exotic Round Island fruits. The mean is indicated by a solid dot, the interquartile range by the rectangle, the standard deviation by bars and outliers by open circles. Lomtor= *Lomatophyllum tormentorii,* Myomau= *Myoporum mauritianum,* Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*.

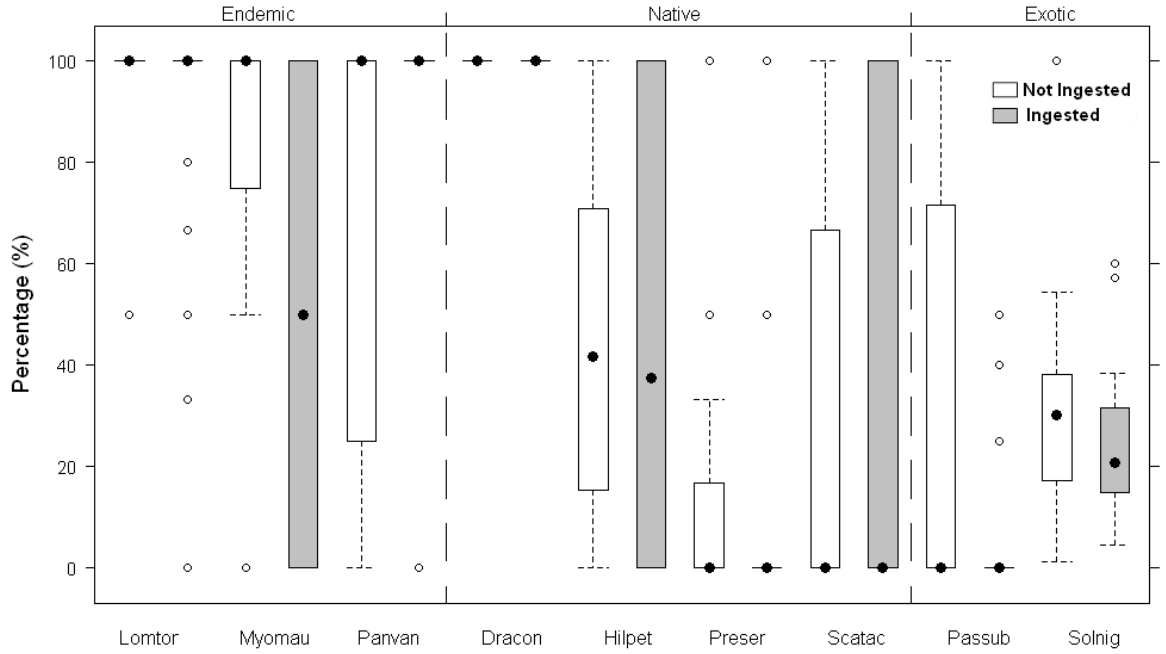

Figure 4. Comparisons of the effect of ingestion by Telfair's skink on the survivorship of native, endemic and exotic Round Island fruits. The mean is indicated by a solid dot, the interquartile range by the rectangle, the standard deviation by bars and outliers by open circles. Lomtor= *Lomatophyllum tormentorii,* Myomau= *Myoporum mauritianum,* Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*..

Table 4 Summary of the GLMs comparing the effect of ingestion by Telfair's skink on the germination time, percentage germination and percentage survivorship of native, endemic and exotic Round Island fruits. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold and Lomtor= *Lomatophyllum tormentorii,* Myomau= *Myoporum mauritianum,* Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia petiolaris*, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*.

Status	Species	Number of days to germinate			Percentage germination			Percentage survivorship		
		d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Endemic	Lomtor	1,23	10.24	**0.004**	1,58	3.53	0.060	1,35	0.06	0.804
Endemic	Myomau	1,25	2.85	0.104	1,58	6.23	**0.013**	1,26	1.20	0.272
Endemic	Panvan	1,18	0.23	0.639	1,58	0.97	0.324	1,18	2.37	0.123
Native	Dracon	1,29	0.04	0.843	1,58	1.25	0.263	1,29	0	1
Native	Hilpet	1,30	6.86	**0.014**	1,58	0.27	0.606	1,30	0.01	0.979
Native	Preser	1,28	4.31	**0.047**	1,58	0.01	0.9349	1,28	0.30	0.583
Native	Scatac	1,45	0.39	0.533	1,58	3.99	**0.046**	1,45	0.46	0.500
Exotic	Passub	1,32	0.01	0.999	1,58	0.07	0.793	1,32	4.26	**0.039**
Exotic	Solnig	1,57	8.75	**0.005**	1,58	1.86	0.173	1,57	3.44	0.064

Percentage germination of ingested compared to not ingested fruits of *Myoporum mauritianum* and *Scaevola taccada*, but not of other species, significantly increased (Fig. 3 & Table 4 & 5 & Appendix III). Percentage survivorship of ingested compared to not ingested fruits decreased significantly in the two exotic species *Passiflora suberosa* and *Solanum nigrum*, but not in other species (Fig. 4 & Table 4 & 5 & Appendix III)

Table 5 Summary of the effects of gut passage on the mean germination time, percentage germination and percentage survivorship of native, endemic and exotic Round Island species. Where + = enhancement, 0 = neutral ; - = inhibition and Lomtor= *Lomatophyllum tormentorii,* Myomau= *Myoporum mauritianum,* Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*.

Status	Family	Species	Number of days to germinate	Percentage germination	Percentage survivorship
Endemic	Liliacea	Lomtor	**+**	0	0
Endemic	Myoporacea	Myomau	0	**+**	0
Endemic	Pandanacea	Panvan	0	0	0
Native	Dracaenacea	Dracon	0	0	0
Native	Boraginacea	Hilpet	**+**	0	0
Native	Verbenacea	Preser	**+**	0	0
Native	Goodeniacea	Scatac	0	**+**	0
Exotic	Passifloracea	Passub	0	0	**-**
Exotic	Solanacea	Solnig	**+**	0	-

Mechanisms responsible for the effect of gut passage on seedlings germination time, percentage germination and survivorship

To experimentally disentangle the effects of the three factors propagule type, gut passage and faeces, in the process of skink ingestion in the first experiment, a second experiment was conducted. Manual depulping of the fruit significantly reduced the germination time and the percentage germination, but not the survivorship of the experimental species (Table 6). Gut passage significantly reduced the germination time, but not the percentage germination or the survivorship (Table 6). The presence of faecal material significantly increased the percentage germination, but had no effect on germination time or survivorship (Table 6). A large part of the variation in germination time, percentage germination and survivorship was explained by the status of a species and its identity, even after accounting for variation explained by fruit and seed size, and seed density. These fruit traits explained a large part of the variation for the dependent variable germination time, for the survivorship fruit size was particularly important. Generally germination time and survivorship decreased with decrease in fruit and seed size and decreased with increase in seed density. Percentage germination decreased with increase in seed density.

Table 6. Summary of the GLMs explaining variation in germination time, percentage germination and seedlings survivorship of all the Round Island species tested in this experiment. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; propagule type refers to seeds or fruits; gut passage to gut passage or no gut passage, and faeces to with or without faeces. Statistical significance indicated with bold.

Status	Number of days to germinate			Percentage germination			Percentage survivorship		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Fruit size	1,1029	1167.19	**<0.0001**	1,1588	2.03	0.154	1,1053	186.65	**<0.0001**
Seed size	1,1028	671.74	**<0.0001**	1,1587	0.32	0.570	1,1052	3.85	**0.049**
Seed density	1,1027	3902.01	**<0.0001**	1,1586	30.12	**<0.0001**	1,1051	14.72	**<0.0001**
Status	2,1025	515.34	**<0.0001**	2,1584	49.39	**<0.0001**	2,1049	40.49	**<0.0001**
Species	3,1022	603.56	**<0.0001**	3,1581	37.75	**<0.0001**	3,1046	60.70	**<0.0001**
Propagule type	1,1021	9.05	**0.003**	1,1580	9.76	**0.001**	1,1045	0.35	0.553
Gut passage	1,1020	32.52	**<0.0001**	1,1579	1.59	0.207	1,1044	0.97	0.325
Faeces	1,1019	0.06	0.806	1,1578	4.90	**0.027**	1,1043	0.01	0.921

It is apparent that variations in germination time, percentage and survivorship are associated with fruit traits, such as size, seed size, seed density and thickness of the fruits' pulp. Thus when considering which factors had an effect at the status level we grouped seed

and fruit size and seed density in a category called fruit traits, which result in keeping species as co-variable.

Table 7. Summary of the GLMs explaining variation in germination time of native, endemic and exotic Round Island species. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; propagule type refers to seeds or fruits; gut passage to gut passage or no gut passage, and faeces to with or without faeces. Statistical significance indicated with bold.

Status	Endemic			Native			Exotic		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Fruit traits	2,231	619.87	**<0.0001**	3,459	491.27	**<0.0001**	1,283	845.72	**<0.0001**
Propagule type	1,230	5.65	**0.018**	1,458	1.74	0.188	1,282	5.72	**0.017**
Gut passage	1,229	28.21	**<0.0001**	1,457	15.40	**<0.0001**	1,281	6.59	**0.012**
Faeces	1,228	0.74	0.389	1,456	0.01	0.976	1,280	3.78	0.053
Propagule type: Gut passage	1,227	0.34	0.56	1,455	1.56	0.213	1,279	0.01	0.947
Propagule type: faeces	1,226	6.56	**0.011**	1,454	1.08	0.299	1,278	0.24	0.62

Fruit traits explained most of the variation in germination time, followed by gut passage for all dependent variables (Table 7 & Appendix IV). Manual depulping of the fruit significantly reduced the time to germinate for the endemic and exotic species (Table 7 & Appendix IV). The presence or absence of faecal material had no effect on any of the dependent variables (Table 7 & Appendix IV).

Table 8. Summary of the GLMs explaining variation in percentage germination of native, endemic and exotic Round Island species. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; propagule type refers to seeds or fruits; gut passage to gut passage or no gut passage, and faeces to with or without faeces. Statistical significance indicated with bold.

Status	Endemic			Native			Exotic		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Fruit traits	2,447	0.83	0.434	3,716	34.04	**<0.0001**	1,358	117.23	**<0.0001**
Propagule type	1,446	1.10	0.293	1,715	17.90	**<0.0001**	1,357	1.23	0.267
Gut passage	1,445	0.46	0.497	1,714	1.10	0.295	1,356	4.54	**0.033**
Faeces	1,444	0.01	0.973	1,713	1.03	0.310	1,355	0.72	0.398
Propagule type: Gut passage	1,443	13.66	**<0.0001**	1,712	1.34	0.248	1,354	0.42	0.518
Propagule type: faeces	1,442	1.34	0.247	1,711	0.01	0.980	1,353	0.11	0.74

Fruit traits explained a large part of the variation in the percentage germination among native and exotic species (Table 8 & Appendix IV). Manual depulping of the fruit significantly increased the percentage germination of native species (Table 8 & Appendix IV). Gut passage through skinks significantly increased the percentage germination for the exotic species (Table 8 & Appendix IV).

Variation in fruit traits among species accounted for the variation in the survivorship of endemic and native species, but not for the two exotic species (Table 9 & Appendix IV). For exotic species, however, gut passage decreased the survivorship significantly (Table 9 & Appendix IV).

Table 9. Summary of the GLMs explaining variation in seedlings survivorship of native, endemic and exotic Round Island species. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; propagule type refers to seeds or fruits; gut passage to gut passage or no gut passage, and faeces to with or without faeces. Statistical significance indicated with bold.

Status	Endemic			Native			Exotic		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Fruit traits	2,254	23.25	**<0.0001**	3,460	73.79	**<0.0001**	1,283	0.62	0.43
Propagule type	1,253	2.97	0.085	1,459	0.25	0.619	1,282	0.15	0.703
Gut passage	1,252	0.96	0.328	1,458	0.24	0.623	1,281	4.67	**0.031**
Faeces	1,251	0.51	0.476	1,457	0.01	0.965	1,280	1.97	0.161
Propagule type: Gut passage	1,250	0.01	0.912	1,456	0.33	0.565	1,279	0.72	0.394
Propagule type: faeces	1,249	1.79	0.180	1,455	1.36	0.244	1,278	1.04	0.308

The effect of manual depulping, gut passage and deposition in faeces on the germination time, percentage germination and survivorship of each species is summarised in Table 10.

Table 10. Factors responsible for the germination time, percentage germination and seedling survivorship of each species. Refer to Appendices V and VI for statistical details. * denotes factors which work in combination to have a response.

	Germination time			Percentage germination			Survivorship		
	Depulping	Gut passage	Faeces	Depulping	Gut passage	Faeces	Depulping	Gut passage	Faeces
Lomtor		X		X*	X*				
Myomau	X, X*	X	X*				X		
Panvan								X	
Dracon	X			X					
Hilpet		X							
Preser	X	X		X					
Scatac		X		X	X				
Passub									
Solnig	X*		X, X*		X			X	

Discussion

We found that fruits which were ingested by Telfair's skink differed in their germination time, percentage germination and survivorship. Traveset (1998) found that ingestion by reptiles modified the germination time in most cases (63%), accelerating it more often (47%) than delaying it (16%). Our results corroborated this; the germination time changed in less than half of the cases (44%), in which it was accelerated in all (100%). (Traveset 1998) also found that when ingested by reptiles, percentage germination was affected in 44% of cases;

28 % were positive and 16 % negative. In support of this, we found that percentage germination was only affected in 23 % of cases of which all increased. The survivorship was only affected in 23 % of cases of which all decreased.

A key finding of this study is that endemic, native and exotic plant species were differently affected by the skink's ingestion. Ingestion reduced germination time for endemic species with no effect for native and exotic species. Percentage germination increased for the endemic species, but not in native or exotic species, whereas, the survivorship of the two exotic species was decreased in contrast to the endemic and native species. These effects were consistent over the two experiments.

According to our analyses the differences in germination time, percentage germination and survivorship among species was mainly due to variation in fruits traits, gut passage and the depulping of the fruit. This is consistent with the conclusions of (Lieberman & Lieberman 1986), (Grice 1996) and (Traveset 1998). However, it is important to emphasize that gut passage had differential effects depending on status of each species.

Effect of Telfair's skink ingestion on seedlings germination time, percentage germination and survivorship

In general, in ecosystems lacking Telfair's skinks and other frugivorous reptiles, the exotic species germinated quicker and had a higher percentage germination than the native and endemic species tested. Consequently, these exotics can exploit resources before the native and endemic species germinate, giving them a growth advantage (Loiselle 1990). Initially, they are more competitive at the seedling establishment stage. However, the lower survivorship of exotics means that natives and endemics have a higher probability of persisting, once germinated. Similar results were found by (Perez-Fernandez *et al*. 2000) who report a higher germination time of native weeds in south-western Australia. This may be one of the reasons why exotic plant species are so successful in invading oceanic islands worldwide (D'Antonio & Meyerson 2002).

Clearly, when there are no seed dispersers and fruits are left to germinate, exotics plant species have a competitive advantage. However, the competitive outcome between exotic, native and endemic species is altered when the fruits are ingested by a seed disperser, such as the Telfair's skink. Although all tested plant species benefited from Telfair's skink ingestion in terms of a shorter germination time and an increase in percentage germination, endemic plant species benefit relatively more than native and exotic species. This implies strong adaptation processes between the endemics plants and their endemic seed dispersers

(Olesen & Valido 2003). While increasing the survivorship of endemic and native species, ingestion by Telfair's skinks reduced the survivorship of the exotic species significantly. These findings dispels initial fears that translocated Telfair's skinks would accelerate the spread of alien plant species thereby having a detrimental impact on the ongoing restoration efforts of recipient sites (Pernetta *et al*. 2005). Although skinks will spread exotic species, they are expected to hinder their survivorship.

Being ingested had mixed effects on the germination time, percentage and survivorship of each species. This was dependent on species' characteristics, such as fruit and seed size, the thickness of the fruit's epicarp and seed husk thickness, which is in a line with findings of (Traveset 1998). For example, the percentage germination and survivorship of *Premna serratifolia* decreased after ingestion by skinks. Percentage survivorship also decreased for *Myoporum mauritianum, Hilsenbergia petiolaris, Passiflora suberosa* and *Solanum nigrum*. The aforementioned species produce small seeds (Table 1). We inferred that the main cause for these negative effects post-ingestion was the smaller seed size, which might increase the risk to abrasive damage from the gut passage (Van der Pijl 1982). This interpretation is further corroborated by the results from species with larger seeds like *Dracaena concinna* and *Scaevola taccada*, which all benefited from ingestion by skinks. However, germination or survivorship did not increase for *Pandanus vandermeerschii* which is not an overly fleshy fruit. Thereby, we infer that Telfair's skinks, which received limited nutritional gain from ingesting these large seeds, were attracted for the purpose of dispersal gains (Connell 1971; Hulme 1998; Janzen 1970).

After four days most of the Telfairs' skinks had defecated the fruits and seeds. Skinks which were fed whole fruits defecated most of the seeds after one day, whereas they took two to three days for the manually depulped fruits, which were dry seeds. This supports findings that fleshy fruits have high water content and contain a chemical or chemicals with a laxative effect that reduces gut passage time (Cipollini & Levey 1997; Murray *et al*. 1994; Wahaj *et al*. 1998). However, lizard gut passage time is also often dependent on temperature and activity; being faster when temperatures are higher and the animals are more active (Whitaker 1987). Contrary, *Pandanus vandermeeschii* seeds, which are not particularly fleshy, were mostly defecated after one day. This could be attributed to their significantly larger size and the number fed to each skink.

Mechanisms responsible for the effect of ingestion on seedlings germination time, percentage germination and survivorship

Differences in the germination time were mainly due to the fruit traits (fruit size, seed size and seed density), gut passage and manual depulping of the fruits. Seed size also played an important role. Smaller seeds are generally found to germinate quicker than larger seeds (Banovetz & Scheiner 1994; Turnbull *et al*. 1999). The removal of the skin or flesh around the seed, which usually contains active germination inhibitors, enhances germination (Gardener *et al*. 1993; Traveset 1998). Unaided, the flesh and skin will slowly decompose, resulting in a longer germination time. Consequently, gut passage and depulping accelerated its removal, enabling seeds to germinate quicker (Gardener *et al*. 1993; Traveset 1998).

Percentage germination was enhanced by fruit traits (fruit and seed size), manual depulping and germination in faeces. The removal of the fruit pulp facilitates the germination of weak seedlings which may struggle to emerge when the mesocarp and exocarp fails to decompose properly (Gardener *et al*. 1993; Traveset 1998). Deposition in faeces can offer seeds protection against infection, provision of a moist microsite and the addition of nutrients (Grice 1996), which may have contributed to the observed increase in the proportion of germinated seeds in this study.

Fruit traits played an important role in seedling survivorship. Higher seed density increases intraspecific seedling competition, and ultimately seedling mortality. In contrast, species with low seed density experience less intraspecific competition (Loiselle 1990). Although smaller seeds germinated quicker at a higher proportion, their survivorship was lower than that of larger seeds. Larger seeds, though generally exhibiting a relatively low germination rate, have usually sufficient resources to develop a more resistant seedling (Banovetz & Scheiner 1994; Turnbull *et al*. 1999).

An important finding of this study is that gut passage significantly decreased survivorship only of the exotic, but not of the endemic and native plant species, even after accounting for variation in fruit traits. A reduction in survivorship of ingested fruits may result from the removal of the pulp, which may provide nutrients essential for growth and survival (Traveset 1998), may hamper seedling growth. Whereas endemic species with their generally larger seeds could be less reliant on the fruit pulp for nutrients as they have larger seed reserves. However, manual depulping was not significant in our study, thus the reason is more likely that an exposure to digestive fluids may have result in the removal of much of the protective mesocarp, thereby damaging the seed embryo. Seeds with soft seed coats, such as the two exotic species *Solanum nigrum* and *Passiflora suberosa*, are especially prone to damage (Gardener *et al*. 1993; Murphy *et al*. 1993).

The fruit traits of the species studied here are representative of the traits of the endemic, native and exotics species in general on Mauritius (Vaughan & Wiehe 1937). Thus it is conceivable that the development of relatively large, fleshy fruits of endemic, and to a lesser degree, native species is part of an adaptation to reptile ingestion and dispersal, as larger fruits are less adversely affected by gut passage. The two exotic species *S. nigrum* and *P suberosa* are dispersed by birds but not reptiles in their original distribution range (Rouillard & Guého 1999; Traveset 1998). Thus, in these exotic species, the lack of adaptation to reptile ingestion may be the reason for the observed decrease in survivorship after gut-passage. Although variation in fruit traits among status groups explained most of the variation in germination success and survivorship, our result that the status:gut passage interaction remained significant after accounting for variation explained by fruit traits, suggests that not only differences in fruit traits explained the differential effects of gut passage for endemic, native and exotic species. These differences resulted from their endemic, native and exotic status and different degree of adaptation to ingestion by reptiles. So in the future it would be interesting to investigate if this extra variation could be explained by chemicals substances present in the fruits. These chemicals could help to reduce the impact of ingestion on the seeds, for example by reducing gut passage time (Cipollini & Levey 1997; Murray *et al*. 1994; Wahaj *et al*. 1998).

Telfair's skinks spread seeds, regardless of whether they are of exotic, native or endemic origin. Fortunately, they increased the percentage germination of endemic species, while decreasing the survivorship of the exotic species. The translocation of the Telfair's skinks to historic distribution or their use as analogues for extinct species should thereby re-establish ecosystem functions with positive cascading effects. Our study is one of the first studies showing that reintroduction can make ecosystems more resistant to invasions. This would benefit restoration efforts in which the ultimate goal is to establish a self-sustaining ecosystem.

Many Mauritian native and endemic plant species are rare and suffering from low germination success. Their propagation in nurseries has proved difficult (D'Antonio & Meyerson 2002). Incorporating past plant-animal interactions in selecting propagation methods has rarely been attempted (Perrow & Davy 2002). Our findings, however, clearly highlight the need to include endemic animals to enhance germination success and percentage survivorship.

Further work is needed to investigate the effects that translocated skinks have on the long-term fate of fleshy fruit species and ultimately on the plant community composition on

their recipient islands. We recommend conducting a similar study to investigate what effects gut passage through the reintroduced analogue tortoises have on larger fruits species and exotic grasses on Round Island. Comparable results would hugely benefit the conservation and restoration of this island and other candidate islands for the translocation of reptiles and the introduction of reptile analogue species.

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Appendix I Comparisons of the effect of gut passage on the germination time, percentage germination and percentage survivorship of native, endemic and exotic Round Island fruits. Results were calculated from fruits ingested or not ingested by Telfair's skink

	Number of days to germinate		Percentage germination		Percentage survivorship	
Status	Not ingested	Ingested	Not ingested	Ingested	Not ingested	Ingested
Endemic	91.0 ± 34.9	74.9 ± 37.3	6.90	22.80	76.40	79.20
Exotic	35.8 ± 29.7	40.7 ± 31.9	25.20	34.50	32.60	9.45
Native	87.9 ± 23.4	89.3 ± 28.8	17.70	26.10	36.80	50.70

Appendix II. Summary of the GLMs used to compare the effect of ingestion by Telfair's skink on the germination time, percentage germination and percentage survivorship of native, endemic and exotic Round Island fruits. d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold.

Status	Number of days to germinate			Percentage germination			Percentage survivorship		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Endemic	1,70	2.99	0.088	1,178	9.49	**0.002**	1,83	0.01	0.948
Exotic	1,91	0.01	0.909	1,118	1.24	0.265	1,91	2.39	**0.007**
Native	1,138	0.02	0.89	1,238	2.51	0.113	1,138	1.24	0.265

Appendix III Comparison of the germination time, percentage germination and percentage survivorship of native, endemic and exotic species (a) that were not ingested or (b) that were ingested by Telfair's skinks on Round Island.

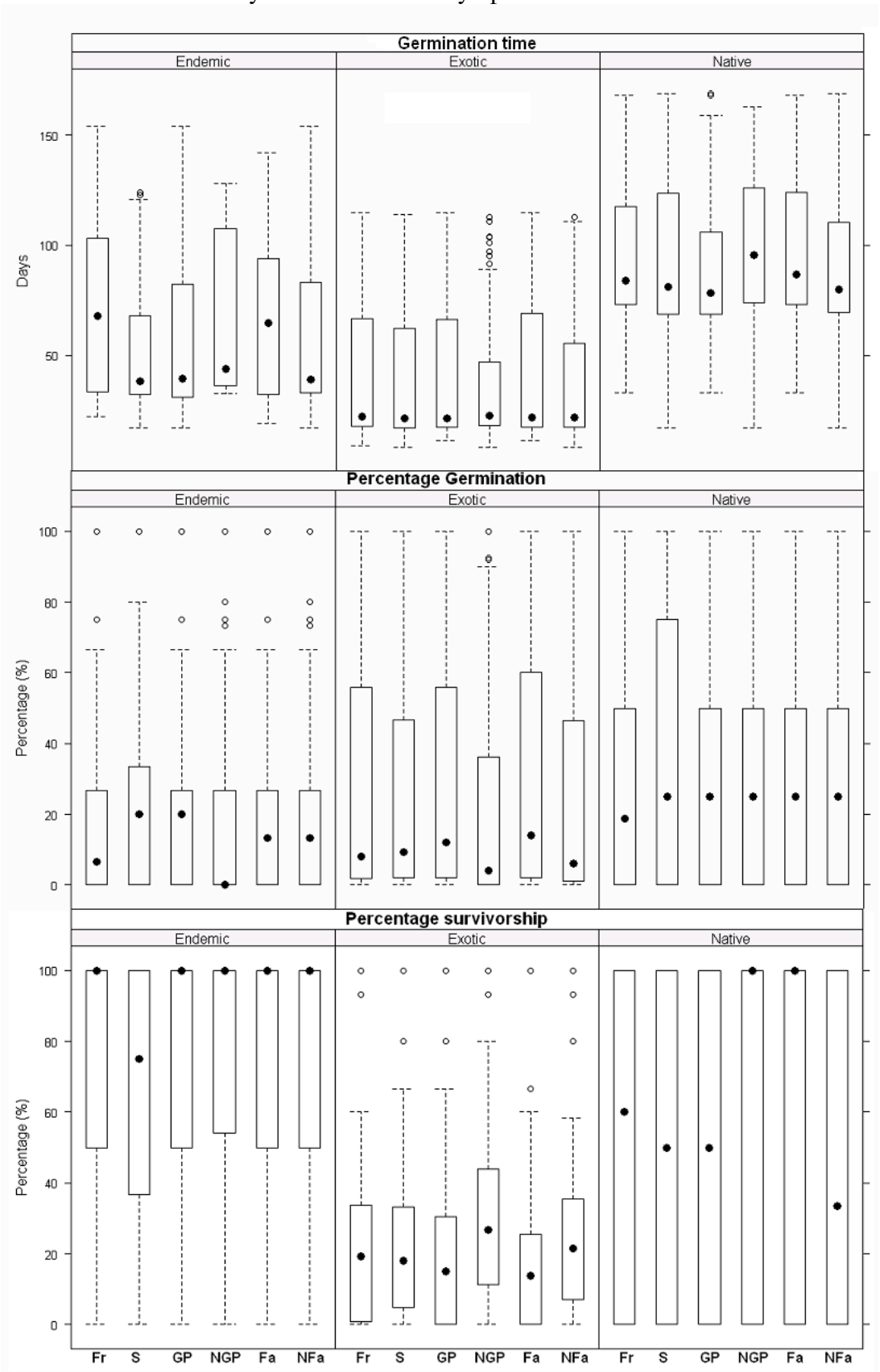
(a)

Status	Scientific name	Mean number of days to germinate	Percentage germination	Percentage survivorship
Endemic	*Lomatophyllum tormentorii*	38	3.1	92.9
Endemic	*Myoporum mauritianum*	115	7.5	77.8
Endemic	*Pandanus vandermeeschii*	105	10.0	66.7
Native	*Dracaena concinna*	129	15.0	100.0
Native	*Hilsenbergia petiolaris*	73	10.6	41.2
Native	*Premna serratifolia*	84	18.3	18.2
Native	*Scaevola taccada*	86	26.7	31.3
Exotic	*Passiflora suberosa*	83	2.7	50.0
Exotic	*Solanum nigrum*	23	44.7	28.5

(b)

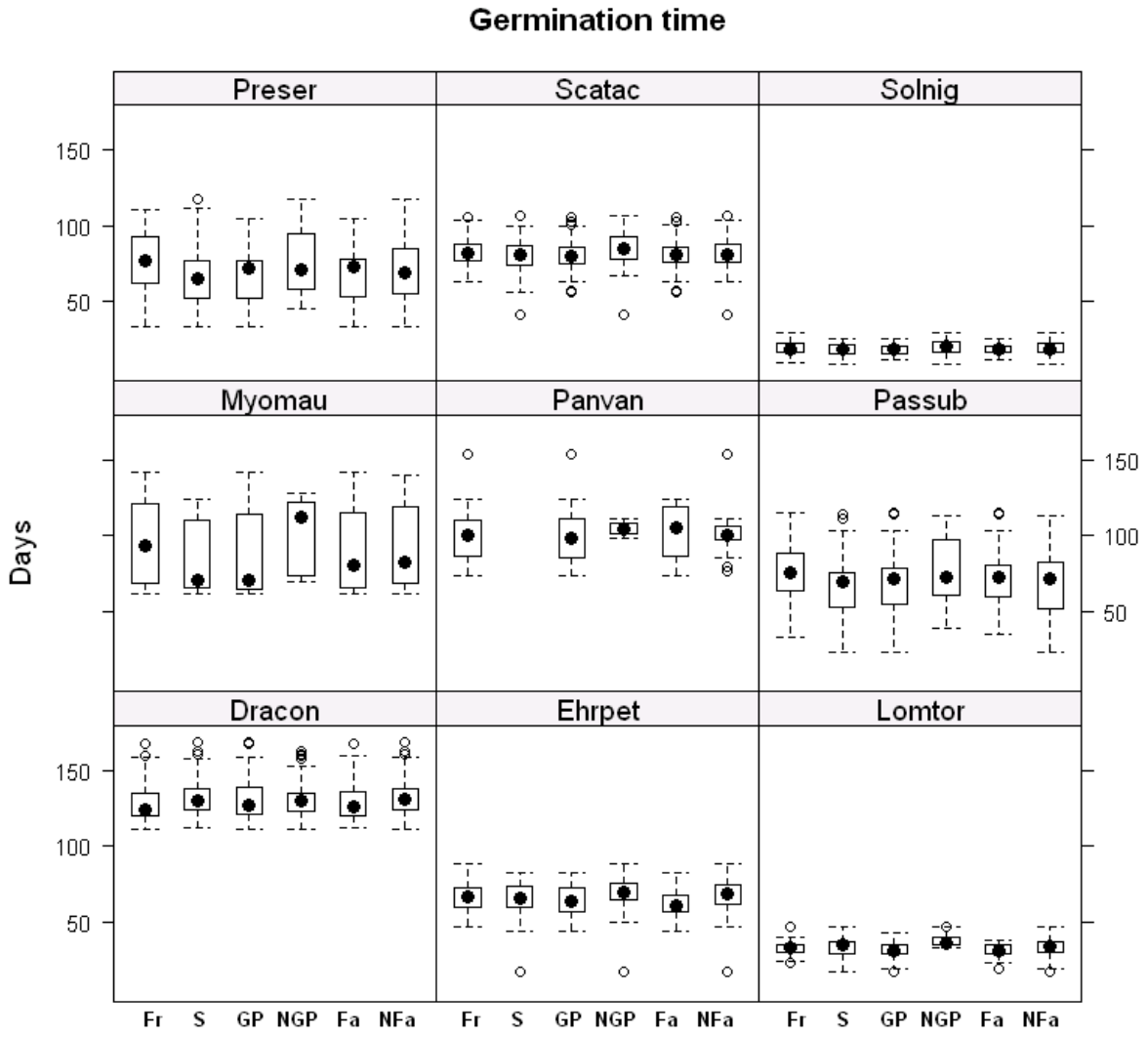
Status	Scientific name	Mean number of days to germinate	Percentage germination	Percentage survivorship
Endemic	*Lomatophyllum tormentorii*	32	17.1	89.8
Endemic	*Myoporum mauritianum*	98	32.5	56.0
Endemic	*Pandanus vandermeeschii*	102	18.8	92.3
Native	*Dracaena concinna*	130	26.7	100.0
Native	*Hilsenbergia petiolaris*	63	6.9	44.3
Native	*Premna serratifolia*	70	19.2	10.7
Native	*Scaevola taccada*	84	51.7	37.5
Exotic	*Passiflora suberosa*	76	3.9	6.1
Exotic	*Solanum nigrum*	18	65.1	11.6

Appendix IV. The effect of the different treatments on the germination time, percentage germination and percentage survivorship of the species at the status level, endemic, exotic and native. Where Fr= fruit, S= seed, NGP= no gut passage, GP= gut passage, Fa= Faeces and NFa= no faeces. The mean is indicated by a solid dot, the interquartile range by the rectangle, the standard deviation by bars and outliers by open circles.

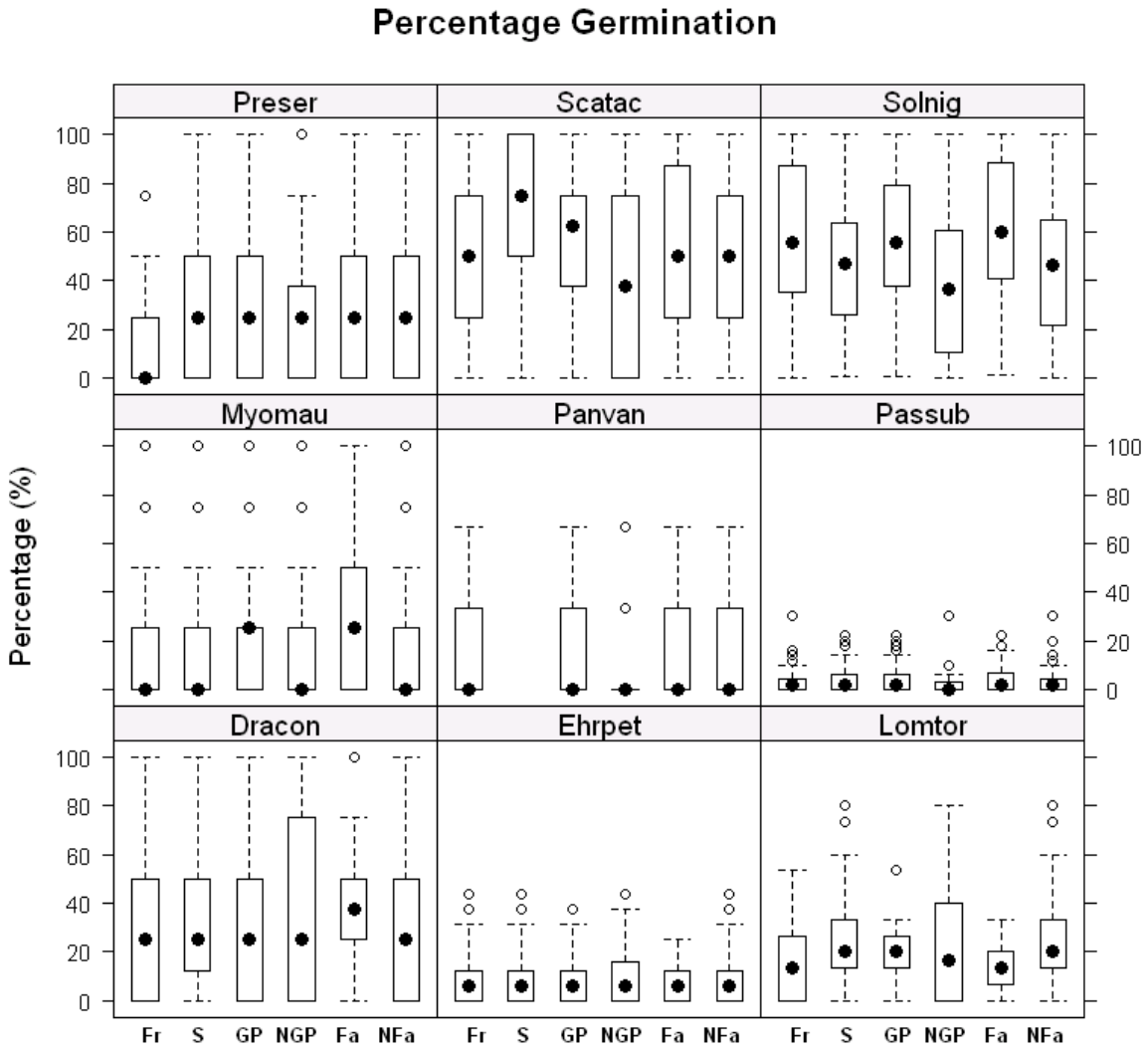


Appendix V. The effect of the different treatments on (a) the germination time, (b) percentage germination and (c) percentage survivorship of each species. Where Fr= fruit, S= seed, NGP= no gut passage, GP= gut passage, Fa= Faeces and NFa= no faeces and Lomtor= *Lomatophyllum tormentorii,* Myomau= *Myoporum mauritianum,* Panvan= *Pandanus vandermeerschii,* Dracon= *Dracaena concinna,* Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia,* Scatac= *Scaevola taccada,* Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*. The mean is indicated by a solid dot, the interquartile range by the rectangle, the standard deviation by bars and outliers by open circles.

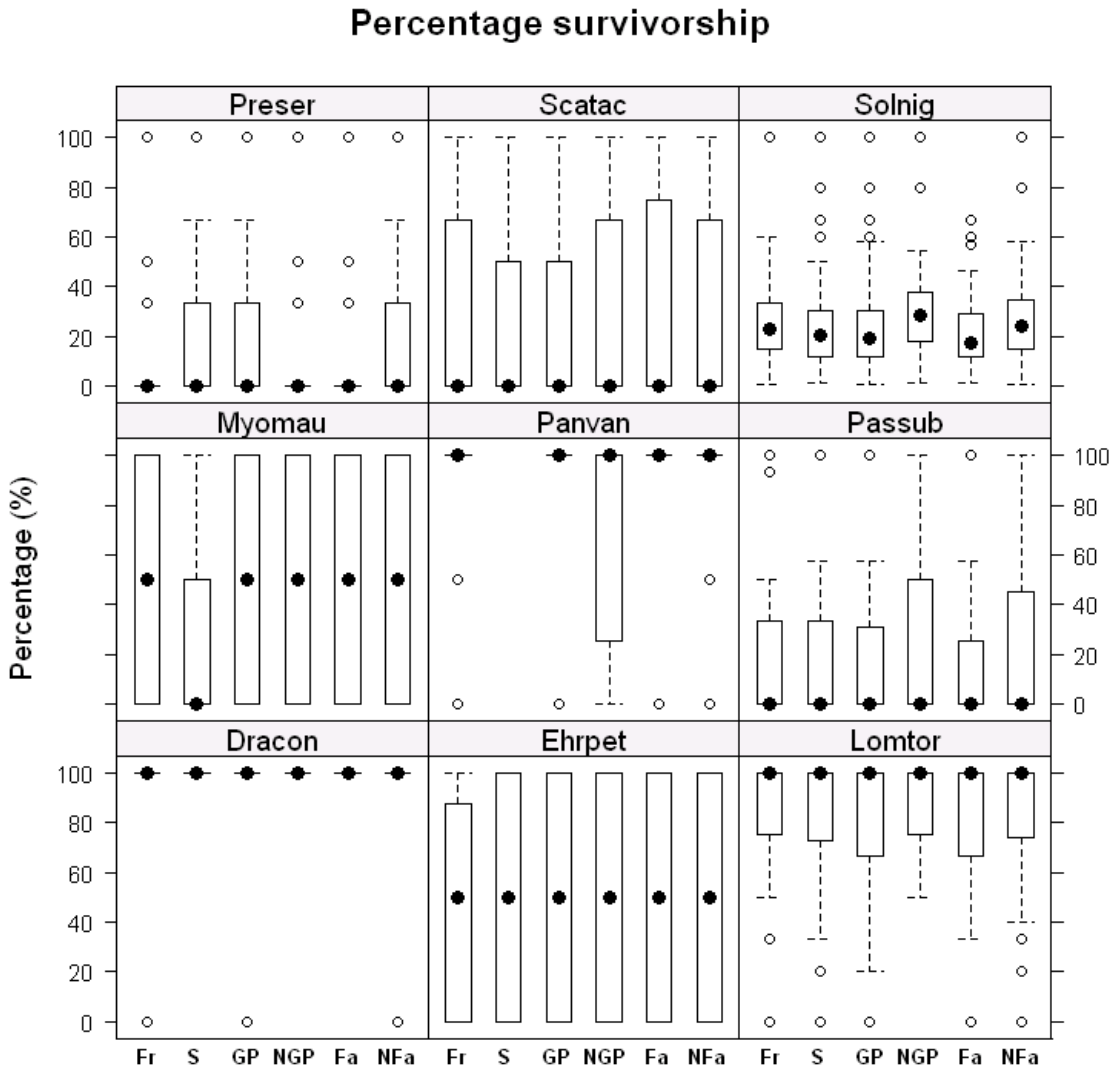
(a)



(b)


Percentage Germination
Preser
Scatac
Solnig
Myomau
Panvan
Passub
Dracon
Ehrpet
Lomtor
Percentage (%)
0
20
40
60
80
100
Fr
S
GP
NGP
Fa
NFa

(c)


Percentage survivorship
Preser
Scatac
Solnig
Myomau
Panvan
Passub
Dracon
Ehrpet
Lomtor
Percentage (%)
0
20
40
60
80
100
Fr
S
GP
NGP
Fa
NFa

Appendix VI. Summary of the GLMs used to determine which factors were responsible for (a) the germination time, (b) percentage germination and (c) percentage survivorship of each species. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold. Where Lomtor= *Lomatophyllum tormentorii*, Myomau= *Myoporum mauritianum*, Panvan= *Pandanus vandermeerschii*, Dracon= *Dracaena concinna*, Hilpet= *Hilsenbergia* petiolaris, Preser= *Premna serratifolia*, Scatac= *Scaevola taccada*, Passub= *Passiflora suberosa* and Solnig= *Solanum nigrum*.

(a) Germination time

Species	Depulping			Gut passage			Germination in feaces		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Lomtom	1,120	0.56	0.456	1,119	49.66	**<0.001**	1,118	0.01	0.962
Myomau	1,81	4.89	**0.030**	1,81	9.52	**0.003**	1,79	0.33	0.570
Panvan	NA	NA	NA	1,27	0.31	0.582	1,26	0.100	0.755
Dracon	1,159	3.12	**0.079**	1,158	0.002	0.969	1,157	1.80	0.182
Hilpet	1,96	0.17	0.680	1,95	3.65	**0.059**	1,94	1.19	0.279
Preser	1,97	6.33	**0.014**	1,96	5.03	**0.027**	1,95	0.001	0.972
Scatac	1,152	1.59	0.210	1,151	5.01	**0.027**	1,150	0.20	0.656
Passub	1,104	2.23	0.138	1,103	1.86	0.176	1,102	2.18	0.143
Solnig	1,177	3.25	**0.073**	1,176	0.04	0.835	1,175	9.60	**0.002**

(b)Percentage germination

Species	Depulping			Gut passage			Germination in faeces		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Lomtom	1,178	2.38	0.123	1,177	0.37	0.545	1,176	2.27	0.132
Myomau	1,178	0.01	0.963	1,177	1.49	0.223	1,176	0.98	0.321
Panvan	NA	NA	NA	1,88	0.55	0.460	1,87	0.51	0.475
Dracon	1,178	3.81	**0.051**	1,177	0.01	0.906	1,176	1.06	0.303
Hilpet	1,178	0.02	0.901	1,177	0.56	0.453	1,176	0.04	0.834
Preser	1,178	11.47	**<0.0001**	1,177	0.02	0.875	1,176	0.66	0.417
Scatac	1,178	6.31	**0.012**	1,177	4.64	**0.031**	1,176	1	0
Passub	1,178	0.21	0.645	1,177	0.63	0.428	1,176	0.09	0.766
Solnig	1,178	1.84	0.175	1,177	3.94	**0.047**	1,176	0.63	0.428

(c)Survivorship

Species	Depulping			Gut passage			Germination in faeces		
	d.f.	*F*	*P*	d.f.	*F*	*P*	d.f.	*F*	*P*
Lomtor	1,142	0.19	0.659	1,141	2.44	0.120	1,140	0.08	0.77
Myomau	1,82	4.43	**0.353**	1,81	1.40	0.236	1,80	1.09	0.297
Panvan	NA	NA	NA	1,27	4.10	**0.043**	1,26	1.09	0.297
Dracon	1,111	1.72	0.189	1,110	0.47	0.492	1,109	1.64	0.200
Hilpet	1,96	0.11	0.738	1,95	0.03	0.867	1,94	0.01	0.943
Preser	1,97	0.59	0.444	1,96	0.25	0.617	1,95	0.72	0.395
Scatac	1,152	0.05	0.824	1,151	0.39	0.531	1,150	0.11	0.743
Passub	1,104	0.08	0.779	1,103	2.08	0.149	1,102	0.65	0.420
Solnig	1,177	0.07	0.789	1,176	2.71	**0.099**	1,175	1.29	0.255

CHAPTER 5

Effect of translocation on the ecology of the Telfair's skink

Chapter 5

Effect of translocation on the ecology of the Telfair's skink

Abstract

Telemetry is a useful approach to monitor animal dynamics, and is becoming an increasingly important tool in wildlife management. We used telemetry to study the Telfair's skink (*Leiolopisma telfairii,* Desjardins, 1831) home range size, behaviour and movement on two offshore Mauritian islands, Round Island and Ile aux Aigrettes. As part of a conservation programme to minimise their risk of extinction, these skinks were recently translocated from Round Island, where they occur at high densities, to Ile aux Aigrettes. The skinks' home range size and movement were significantly greater on Ile aux Aigrettes than on Round Island. The increase was higher for the males than the females. This can be attributed to differences in population density, habitat, climate and food availability. In addition, we conducted a translocation experiment on Round Island to understand what effect this has on the home range size, behaviour and movement of the skinks, especially on their homing capacities. Homing capacities were limited to 25 m from their initial home range. Skinks that were relocated at a distance greater than 50 m had smaller home range size and movement and their behaviour was different to the skinks relocated to a distance of 25 m. Translocation caused weight loss in the skinks and this was positively correlated to translocation distance. Overall, the results show that translocation to Ile aux Aigrettes increased the skinks home range size and movement whereas localised translocation on Round Island to a distance of more than 25 m reduced home range size and movement. The high plasticity and adaptability of the Telfair's skink make it prime candidate for translocation; for example as analogue to the newly described extinct large skink on Réunion. This study provides us with valuable information to improve the way future translocations should be conducted. Although studies spanning several decades may be required to determine whether translocation of the Telfair's skinks are ultimately successful, this study is a useful contribution to this long term monitoring process.

Introduction

Species extinction in the tropics is proceeding rapidly due to the destruction and fragmentation of habitats, and the introduction of invasive alien species (Reaser *et al*. 2007).

This threat to biodiversity increases the importance of improving ways and tools to conserve threatened species (Gipps 1991). One of these tools is translocation (Griffith *et al*. 1989; Kleiman *et al*. 1991; Stanley Price 1991; Wolf *et al*. 1996) which are for conservation reasons, which we define as the intentional movement by humans of an animal or a population of animals from one location to another (Fischer & Lindenmayer 2000; IUCN 1996). Increasing the number of location and distribution of a species minimises its risk of extinction from anthropogenic and stochastic events (Caughley 1994). Translocating animals within their range, or to parts of their former range, is also done for other purposes, such as increasing game numbers for hunting (Griffith *et al*. 1989; Kleiman *et al*. 1991; Stanley Price 1991; Wolf *et al*. 1996). Unfortunately, many translocations are not successful as they lack detailed knowledge of the species' biology and ecology; in some cases the causes of a species' decline were not properly identified and removed prior to translocation (Griffith *et al*. 1989; Kleiman *et al*. 1991; Wolf *et al*. 1996). Thereby, successful translocations rely heavily on detailed knowledge of the life history and biological demands of the species: e.g. habitat preferences, adaptation to local ecological conditions, social behaviour, home-range size, and food requirements (IUCN 1996).

The Telfair's skink, *Leiolopisma telfairii*, an endemic Mauritian reptile was until recently found only on Round Island. To reduce its extinction risk, in February 2007 250 Telfair's skinks were relocated to Gunner's Quoin, where they once occurred (Arnold 2000; Cheke & Hume 2008), and 190 to Ile aux Aigrettes, which offers suitable habitat and is predator-free. Round Island has retained 70 % of its original reptile fauna, due to a lack of introduced predatory mammals and reptiles (Arnold 2000). Mauritius once had one of the most diverse reptile faunas in the world (Arnold 2000). However, since the arrival of the first European colonisers(1598), Mauritius has experienced high rates of extinction caused by extensive habitat destruction and the introduction of numerous non-native species (Cheke & Hume 2008). Consequently, more than 60 % of the endemic reptile fauna was lost from the main island, with some surviving species now restricted to a few offshore island populations (Arnold 2000). Round Island is the most important refuge for native and endemic Mauritian reptiles (North *et al*. 1994). Despite large enough reptile populations (chapter 2), these reptile species, as on other islands, are highly endangered as they are at risk from further anthropogenic and stochastic perturbation (Caughley 1994). Establishing successful populations elsewhere in Mauritius will help secure the future of these reptiles.

The aim of this study was to investigate the home range size, movement patterns and behavioural response of the Telfair's skink to between-island (Round Island and Ile aux

Aigrettes) and localised within-island translocations using telemetry and mark-resighting. For the latter, we moved skinks relatively short distances away from their established home ranges and investigated their homing capacities. We provide essential information for ongoing and future translocation efforts in relation to localised translocations of a population to new habitat, or to increase the distribution range of the Telfair's skink within Mauritius. Incorporating measures of animal behaviour into evaluations of restoration success provides critical information that is not available from simple animal species composition and richness estimates (Lindell 2008). We provide information at individual level, thus improving our understanding of the home range size, movement and behaviour at a more refine scale, which is often ignored in studies at a population level.

Direct observation is regarded as the best method to understand an animal's usage of space and movements (Millspaugh & Marzluff 2001). However, this can be challenging and limited for secretive animals, and may also affect the animal's behaviour (Millspaugh & Marzluff 2001). One solution is to use radio-telemetry (Macdonald 1978), which can provide more accurate information in terms of reptile life history than those obtained from opportunistic direct sightings (Weatherhead & Charland 1985).

Materials and methods

Study species

The Telfair's skink, *Leiolopisma telfairii*, is the largest extant Mauritian skink (Jones 1993), reaching an average length of 276.9 ± 39.2 mm (N = 1498). Sub-fossil evidence indicates that the species was once widespread, occurring on the main island of Mauritius, Flat Island and Gunner's Quoin (Arnold 1980; Cheke & Hume 2008). Until recently, the Telfair's skink survived only on Round Island. In 2006, new populations were established on Ile aux Aigrettes and Gunner's Quoin.

The body of *L. telfairii* is generally a brownish grey, mottled with dark brown spots. The skink shows tail autotomy, which is the ability to drop the tail during a fight or to escape capture. The tail is subsequently regenerated. The skink is largely diurnal and terrestrial (Bullock 1986), however it is also active at night and becomes arboreal to consume fruits and flowers (Jones 1993). Extensive feeding observations and faecal analyses indicate that they are omnivorous; their diet over a period of one year consisted of 19.9 % of plant-, 75.1 % of invertebrate-, 2.3 % of reptile- and 2.7 % of bird- food items (see chapter 3).

Study sites

The study was conducted on Round Island and Ile aux Aigrettes (Fig. 1). Round Island (57°47□03□E, 19°54□03□S) is a basaltic volcanic cone, located 22.4 km off the north coast of Mauritius (Merton *et al*. 1989). This 219 ha island rises 280 m above sea level and can be divided into seven distinct habitat types according to vegetation and substrate (Johansson 2003). The study site was located in the palm forest, on the western slopes of the island, which covers approximately 66 ha., roughly 30% of the island's surface area. Once common on mainland Mauritius, this habitat type is the most widespread on Round Island (Cheke & Hume 2008; Vaughan & Wiehe 1937). It has the highest skink density (see chapter 2).

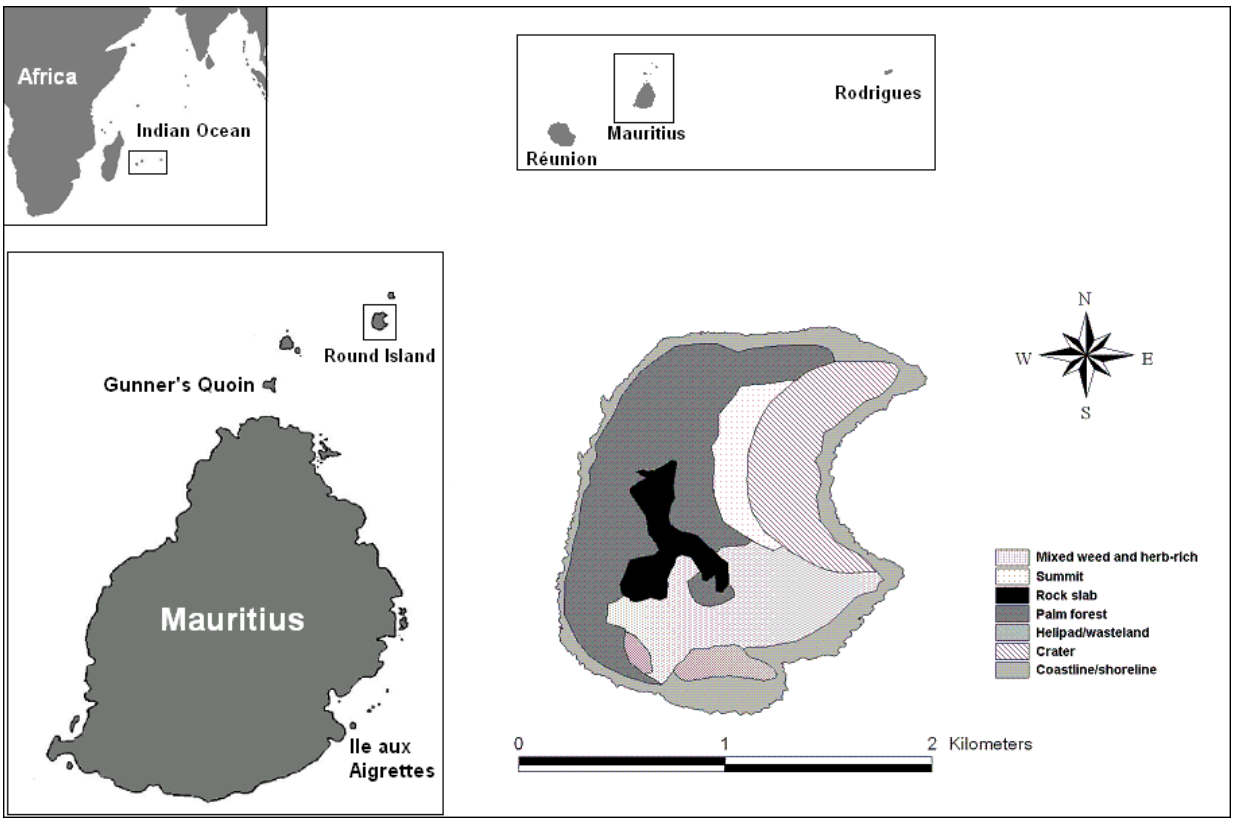


Figure 1. Location of the Mascarene archipelago, Mauritius and selected offshore islands. The seven habitats of Round Island are shown.

Ile Aux Aigrettes (57°73□05□□E, 20°42□03□□S), a 26 ha coralline island with a maximum elevation of 12 m, is located 625 m of the southeast coast of Mauritius (Parnell *et al*. 1989). This island harbours the best-conserved remnants of native coastal and lowland ebony forest in Mauritius (Parnell *et al*. 1989).

Climatic conditions between both islands differ. Round Island is more exposed to wind and waves due to its elevation, the absence of coral reefs and coastline vegetation. This results in a dry hot micro-climate with considerable salt spray, rare rainfall and big variation in temperature between the day and night. Ile aux Aigrettes is more protected with its low

elevation, coral reefs and coastal vegetation. This results in a mild micro-climate with high percentage of humidity, frequent rainfall and unvarying temperature between the day and night.

Skink morphometrics

On the 27th March 2008, 21 male and 25 female healthy adult skinks with a snout-vent length Svl greater than 120 mm were caught in three areas in the palm forest. Twelve male and female skinks each were caught on Ile aux Aigrettes on the 14th April 2008. The skinks were weighed with a Pesola scale (600 g, 5 g accuracy). Their Svl and the width of the base of the tail 10 mm below the vent was measured with a dial calliper (accuracy 0.1 mm). The latter measurement and the weight provided a reliable indication of the health of the animal, as excess fat is stored in the tail (Nicholas C. Cole pers. comm.); the thicker the tail, the healthier the animal. Since skinks can shed their tail, snout-vent length is a more reliable measurement of skink size.

Tagging, spotting and tracking

Round Island skinks were studied from the 28th March to 10th April 2008, and Ile aux Aigrettes skinks from the 15th of April to the 24th of April 2008. In both studies, male and female skinks were treated differently: only the male skinks were equipped with transmitters due to limited funds. The data for the females were obtained through marking and resighting. The females were marked with a number on their back using a non-toxic permanent marker, enabling them to be individually identified. For the home-range analyses only, six female skinks from Round Island and one from Ile aux Aigrettes were excluded from the analysis because there were insufficient fixes (<10 locations; Appendix I) for each of these animals to calculate an accurate home range estimate (Millspaugh & Marzluff 2001).

Only large male skinks were equipped with transmitters to have similar-sized individuals, and because transmitters should not weigh more than 3-5 % of the reptile's body weight (Millspaugh & Marzluff 2001). The capture-location of each skink was marked and the GPS coordinate recorded (Garmin model GPSMap60CS; in decimal degrees, using map datum WGS 84). Each male skink was equipped with a single stage transmitter (Sirtrack Ltd., Havelock North, New Zealand). The transmitter was enclosed in a modified backpack harness (Gerner 2008; Warner *et al*. 2006) made of soft veterinary latex stretch bandages, and attached using superglue.

Tracking of the radio-tagged male skinks began the day after release. Skinks were located with a telemetry receiver R-1000 (Communications Specialists Inc., California, USA) and a three-element Yagi antenna (Sirtrack Ltd, Havelock North, New Zealand). Each male was located four times a day, during each of the time intervals: 06:00–10:00 h, 10:00–14:00 h, 14:00–18:00 h, and 18:00–22:00 h, based on observations of activity patterns (see chapter 2). The order in which the males were located was randomised (Kenward 2001). Females were sighted opportunistically. Each time an animal was found, the time, its GPS position, its behaviour (basking, feeding, hiding, moving, still or social), the substrate (coral, creeper, fern, grass, herb, litter, rock or soil) it was found on and its exposure (sheltered, light, medium, high and fully exposed) to prevailing weather conditions (wind and sun) were recorded.

Movement rate in this study was defined as the mean of the distance moved between two successive locations of the same skink and was expressed as metres per hour (mh^{-1}). Only male movement rate was analysed as the resighting was opportunistic for the females and days could have pass between two consecutive resighting. This would provide bias data, however for informative reason we showed movement for the females.

Within-island translocation experiment

After 28 sightings were obtained for each of the radio-tagged male Round Island skinks (3rd April 2008), they were re-captured and the same morphometric and health information data as at their initial capture was collected. The 21 skinks were then randomly assigned to one of 3 groups (7 per group) to test their response to localised translocation. The first group was released at their point of capture, i.e. not translocated. The second and third groups were relocated 25 m and 50 m away, respectively, in a random direction from the border of their original home ranges, which had previously been identified. The males were subsequently tracked for 7 days (4th - 10th April), before being recaptured and recording their morphometric and health conditions. The backpacks were subsequently removed with no injury to report and the skinks returned to their original home ranges. There was high correlation between morphometrics (weight, snout-vent length, tail length, width of tail) measured. Consequently, we used only weight, which is more representative of the overall body condition of the skink, as an indicator of the effects of the backpack and the translocation distance on the skinks' health.

Calculation of home ranges

We used the kernel density estimator, which estimates the likelihood of finding the animal at any particular location within its home range (Worton 1989) as it is favoured over other home range estimators (Borger *et al*. 2006; Millspaugh & Marzluff 2001). Some studies (Borger *et al*. 2006; Millspaugh & Marzluff 2001) suggest using at least two home range estimators, one of which should be the Minimum Convex Polygon (MCP), as it is widely used and results can thus be easily compared to other home range studies. However, a review of home range estimators by Millspaugh and Marszluff (2001) shows that kernel estimators have better performances than other estimators for low sample sizes, such as in this study, and is not affected by autocorrelation. Contrary to this, MCPs exclude autocorrelation even if it holds biological significance (Cushman *et al*. 2005). Indeed, Börger *et al* (2006) argue that MCPs are highly inefficient and should not be used at all for home range analysis.

We used fixed instead of adaptive kernels, as the latter tend to overestimate the area of the distribution (Seaman & Powell 1996). The least-squares cross-validation (h_{lscv}) smoothing parameter was used as very little bias results from area estimates when used in conjunction with fixed kernels (Seaman & Powell 1996). The 90% kernel was chosen to estimate the total home range area of an individual, as higher percentages are not representative of what happens in reality (Powell 2000), and the 80-90% kernel estimate are the ones least biased by sample size and autocorrelation (Borger *et al*. 2006).

Home ranges were calculated and analysed with the Home Range Extension (Rodgers & Carr 1998), for ArcView® 3·02 GIS (ESRI, Redlands, California, USA), and the extension XTools (DeLaune 2003). Movement was calculated using Animal Movement 2.04 (Hooge & Eichenlaub 1997) for ArcView®3.02 GIS. All maps were created in ArcView 3.2 GIS.

Data analyses

Data were analysed by fitting general (LMs) and generalised linear model (GLMs), using the software package R.2.7.0 (R Development Core Team 2008). To investigate whether translocation affected home range size and if their was a difference in home range size between male and female, a general linear model with island (Round Island and Ile aux Aigrettes) and sex (male and female) and the interaction between the two treatment factors was tested. To meet the assumptions of normality and homoscedasticity the response variable were log transformed. In a second general linear model with size (estimated by snout-vent length) as treatment factor was fitted to verify that variation in home range size for the male of both island was not due to their size. As only large male skinks were chosen and equipped

with transmitters. To meet the assumptions of normality and homoscedasticity the response variable were square-root transformed.

Only within-gender comparisons were done for movement pattern, behaviour, substrate choice, and level of exposure observed on the two islands, because the data collection methods for the males and females differed (radiotracking versus re-sighting). Observations of females were biased towards more apparent behaviours or open substrates; hiding females were harder to spot. General linear model with island (Round Island or Ile aux Aigrettes) as treatment factor was fitted to analyse movement difference between islands for the male only. As the data obtain from the re-sighting for the females was not accurate enough for movement calculation. To meet the assumptions of normality and homoscedasticity the response variable were log transformed.

To explore the effects of island on the proportional response variables behaviour, substrate choise and exposure general linear models (GLMs) with binomial errors distribution were fitted. To account for statistical overdispersion, mean deviance changes were compared with *F*-tests (Crawley 2005).

Separate paired t-tests were used to analyse the effect of the translocation distances of 50 m, 25 m and 0 m (control) on home range size, movement and weight loss. In contrast to skinks translocated 50 m on Round Island, four skinks that were moved 25 m away from their home returned to their original home range (25 m A). This group of skinks was analysed separately from the group of three skinks that established new home ranges (25 m B). The home range of returning skinks was calculated once the skinks had reached the boundary of their former home range. Homing capacities were evaluated by comparing the proportion of skinks that returned to their original home ranges with those that established new home ranges between the three relocated distance treatments using Fisher's Exact test for count data.

To explore the effects of within island translocation on the proportional response variables behaviour, substrate choice and exposure separate general linear models (GLMs) with binomial errors were fitted for each translocation distance (50 m, 25 m, 0 m). For the home range size and movement, the mean values are reported with the standard deviation (SD) in the Results section.

Results

A total of 588 locations for males and 264 locations for the females were recorded for the skinks on Round Island, and a total of 222 locations for the males and 72 locations for female skinks on Ile aux Aigrettes.

Home range size and overlap

Round Island skink home range sizes were determined from 28 locations for the 21 males and between 11 and 25 locations for the 19 females (Appendix I). On Round Island, male skinks (203 ± 141 m^2; range = 50–506 m^2) had the same home range size as the female skinks (214 ± 100 m^2; range = 70–368 m^2). Ile aux Aigrettes skink home range sizes were determined from 18 locations for the 12 males and between 4 and 9 locations for the 11 females (Appendix II). On Ile aux Aigrettes, female skinks (1076 ± 977 m^2; range = 67–2854 m^2) had smaller home ranges than the male skinks (1858 ± 1895 m^2; range = 432–5722 m^2). Overall, regardless of skink gender, home range size were much larger on Ile aux Aigrettes than on Round Island ($F_{1,42}$=63.06, P<0001). The interaction sex:island was significant ($F_{1,41}$=4.82, P=0.032), showing that on Ile aux Aigrettes there is a difference in home range size between male and females. Male having larger home range.

As expected by selecting skinks of the same size (Svl >120 mm), size of skinks had no influence on the home range size on either island (Round Island: $F_{1,42}$=0.223, P=0.639, Ile aux Aigrettes: $F_{1,21}$=0.011, P=0.919).

Skink home ranges overlapped between males and females (Fig. 2 & Table 1) suggesting that they have non-exclusive home ranges, areas with more than 20 % overlap with another home range (cf.(Konecny 1987; Maher & Lott 1995)

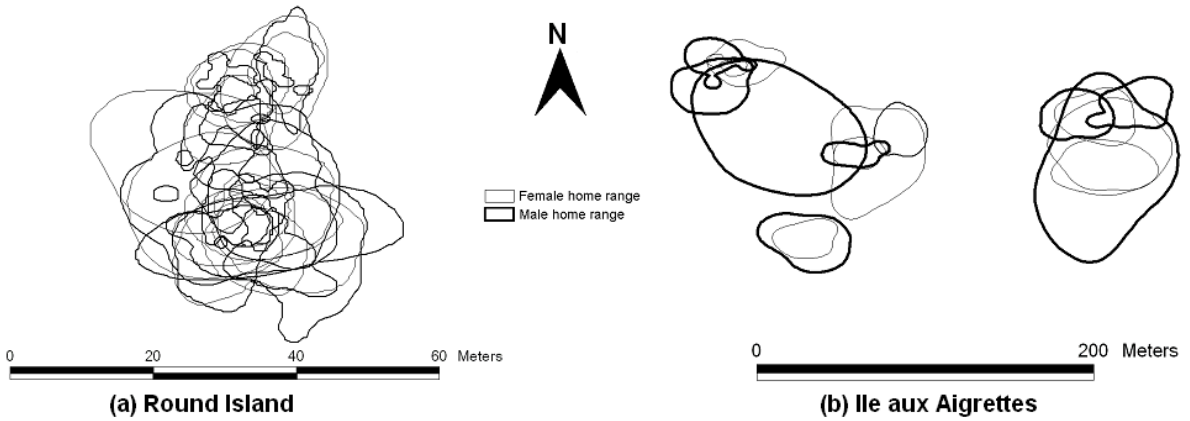


Figure 2. Inter- and intra-gender home range overlaps for Telfair's skinks on Round Island (a) and Ile aux Aigrettes (b).

Table 1. Percentage home range overlaps of male and female Telfair's skinks (*Leiolopisma telfairii)*. If the overlap is more than 20 %, the animals are said to have non-exclusive home ranges. Male-female overlap refers to the percentage of females' home range that overlaps with a male home range whereas female-male overlap refers to the percentage of males' home range that overlaps with a female home range

Skink interaction	Percentage overlap
Round Island male-male	34
Round Island male-female	49
Round Island female-male	41
Round Island female-female	44
Ile aux Aigrettes male-male	29
Ile aux Aigrettes male-female	38
Ile aux Aigrettes female-male	64
Ile aux Aigrettes female-female	55

Difference in ecology between Telfair's skinks from Round Island and Ile aux Aigrettes

Difference in movement between Telfair's skinks from Round Island and Ile aux Aigrettes

The female skinks on Round Island move an average of 0.3±0.04 metres per hour (mh^{-1}) whereas on Ile aux Aigrettes they move an average of 1.32±0.24 mh^{-1}.

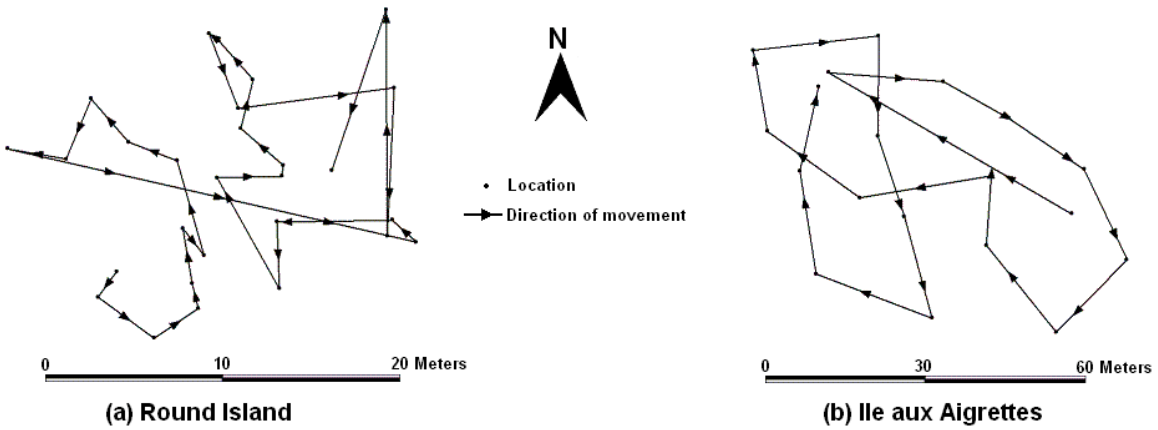


Figure 3. Movement maps for a male Telfair's skink on Round Island during 7 days (a) and Ile aux Aigrettes during 5 days (b). Ile aux Aigrettes skinks have a higher movement rate than Round island ones.

The movement rate of male skinks on Ile aux Aigrettes (3.3±0.82 mh^{-1}) was higher than that of male skinks on Round Island (0.95±0.06 mh^{-1}) ($F_{1,31}$= 50.79, P<0001; Fig. 3).

Difference in behaviour between Telfair's skinks from Round Island and Ile aux Aigrettes

Behaviour frequencies of both male and female skinks differed between the islands (males: $F_{5,186}$= 12.95, P<0001; females: $F_{4,175}$= 6.18, P<0001; Fig. 4). In addition, there were differences between male and female behaviour within islands (Fig. 4).

Table 2 Summary of GLM results comparing the behaviours of male and female skinks on Round Island and Ile aux Aigrettes. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold.

Sex		Basking		Feeding		Hiding		Moving		Still		Social	
	d.f.	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Male	1,31	54.97	**<0.0001**	9.8	**0.004**	13.4	**<0.0001**	9.31	**0.005**	4.35	**0.045**	2.9	0.096
Female	1,35	7.04	**0.011**	13.65	**<0.0001**	0.85	0.36	4.65	**0.037**	2.39	0.13	NA	NA

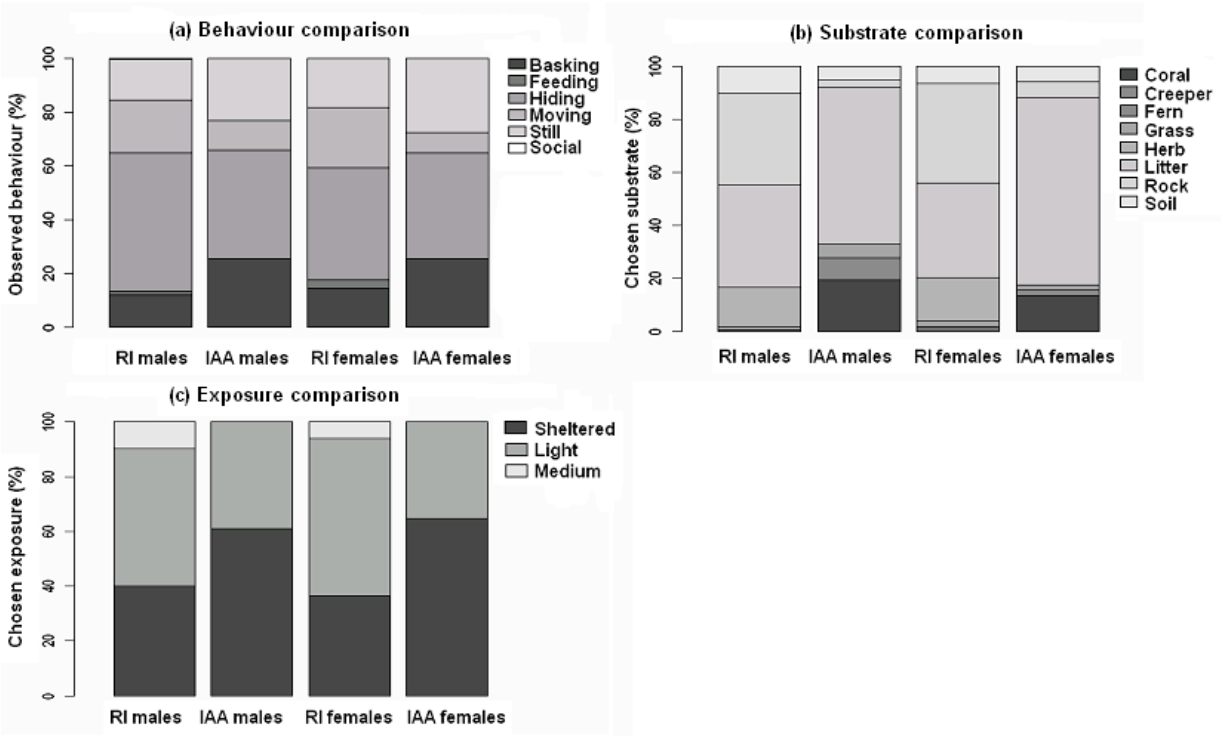


Figure 4. Comparison of (a) behaviour, (b) substrate choice, and (c) exposure levels for male and female skinks from Round Island and Ile aux Aigrettes. Percentages of observed behaviour, substrate and exposure choice were calculated as the proportion of the total number of particular choice or behaviour observed for all the skinks.

Difference in substrate choice behaviour between Telfair's skinks from Round Island and Ile aux Aigrettes

There was a highly significant between-island difference in substrate choice for both genders (males: $F_{7,248}$= 46.04, P<0001; females $F_{7,280}$= 20.27, P<0001). Behaviour differed greatly between islands, but not so much between genders on the same island (Fig. 4 & Table 3).

Table 3. Summary of GLM comparing the substrate choice of male and female skinks on Round Island and Ile aux Aigrettes. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold.

Sex		Coral		Creeper		Fern		Grass		Herb		Litter		Rock		Soil	
	d.f	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Male	1,31	196.2	**<0.0001**	6.6	**0.02**	37.6	**<0.0001**	6.42	**0.017**	86.72	**<0.0001**	21.58	**<0.0001**	54.68	**<0.0001**	3.13	0.086
Female	1,35	52.2	**<0.0001**	6.13	**0.02**	14.36	**<0.0001**	0.36	0.55	45.87	**<0.0001**	29.22	**<0.0001**	18.35	**<0.0001**	1.36	0.25

Difference in levels of exposure behaviour between Telfair's skinks from Round Island and Ile aux Aigrettes

Exposure choice differed significantly between islands, (males, $F_{4,164}$= 631.65, P<0001; females, $F_{4,179}$= 250.25, P<0001) but not between genders on the same island (Fig. 4 & Table 4).

Table 4.. Summary of the GLM comparing the exposure choices of male and female skinks on Round Island and Ile aux Aigrettes. Where d.f. = numerator degrees of freedom, denominator degrees of freedom; statistical significance indicated with bold.

Sex		Sheltered		Light		Medium		High		Exposed	
	d.f	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Male	1,32	34.04	**<0.0001**	9.9	**0.004**	38.01	**<0.0001**	0	1	0	1
Female	1,35	12.65	**0.001**	9.1	**0.005**	14.32	**<0.0001**	0	1	0	1

Effects of localised translocation on the Telfair's skink

Homing capacities of the Telfair's skink

Homing capacities were evaluated by comparing the proportion of skinks that returned to their original home ranges with those that established new home ranges for each of the translocated distance treatments. Homing capacities varied significantly between distance of translocation (P<0.0001). Only 43 % of the skinks translocated to a distance of 25 m remained in their release site, whereas all of those translocated to a distance of 50 m stayed at their release site and established new home ranges (Fig. 6). Control (not translocated) skinks remained at their original home ranges.

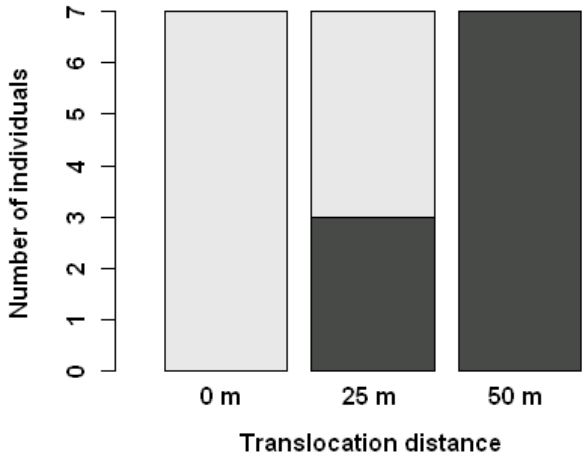


Figure 5. Response of Telfair's skinks on Round Island to localised translocation to different distances from their original home range. Dark shading represents skinks that established new home ranges, whereas those that returned to their original home range are lightly shaded.

Home range size

No significant difference in the home range size before and after translocation for male skinks was found in the 0 m, 25 m A and 25 m B treatment (Figure 6 and Table 5). However, the home range of male skinks that were translocated to a distance of 50 m was significantly smaller than their original one (Fig. 6 & Table 5).

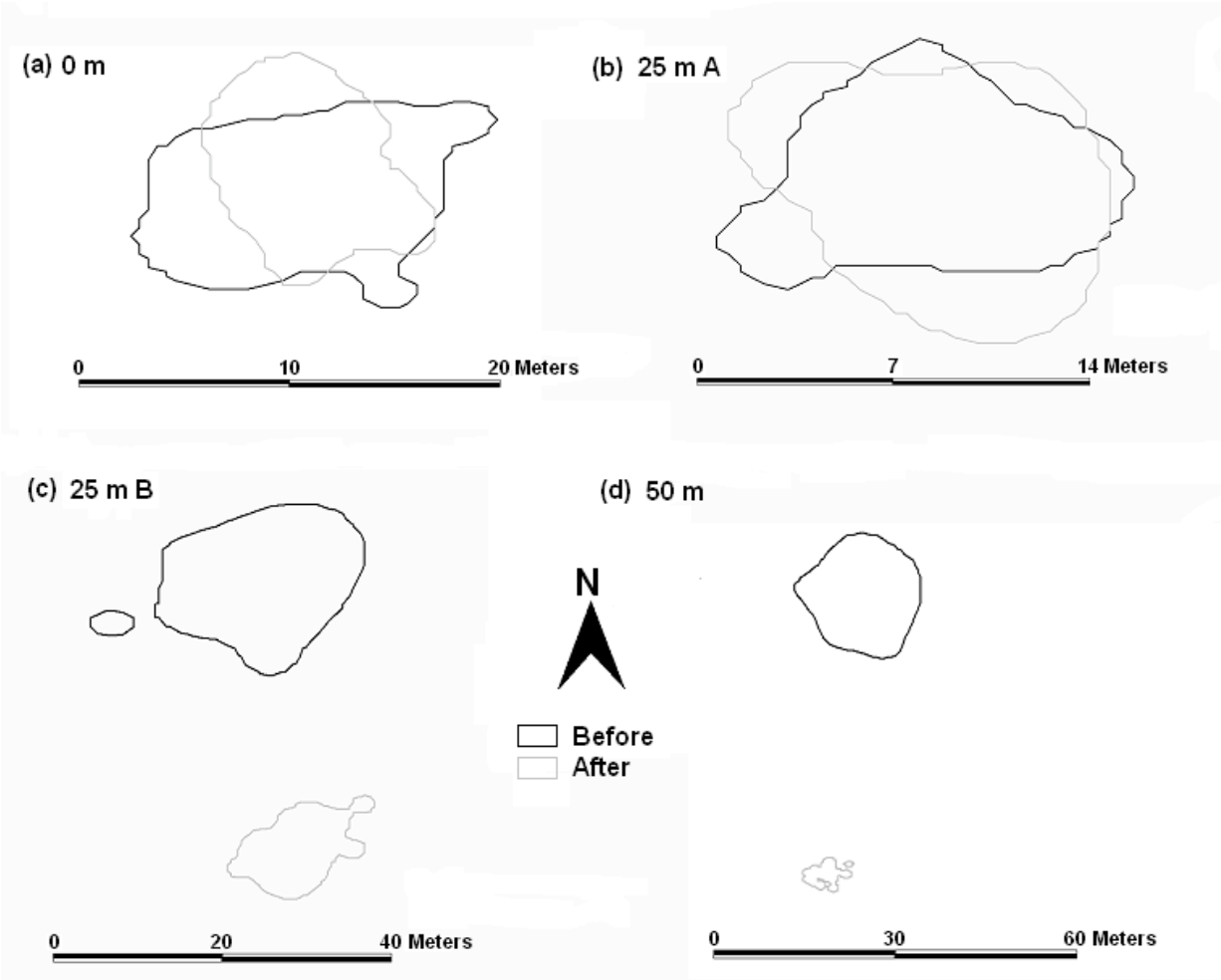


Figure 6. Home range maps for male Round Island Telfair's skinks that were (a) not translocated, (b) translocated 25 m and which returned to their original home range, or (c) established a new home range, and (d) translocated 50 m.

Table 5. Summary of the mean home range sizes and standard deviations before and after translocation of the skinks to different distances. Separate paired t-tests compare home range size before and after translocation. Statistical significance indicated with bold.

Treatment	Before translocation/m²	After translocation/m²	*T*	*P*
0 m	215±62	120±18	1.789	0.124
25 m A	136±43	100±35	0.476	0.666
25 m B	187±75	103±39	1.177	0.360
50 m	235±60	77±14	2.854	**0.029**

Movement

There was no significant difference between the movement rate before and after translocation for the treatments 0 m and 25 m A (Fig. 7 and Table 6). However, for the treatments 50 m and 25 m B the skinks moved significantly less (Table 6).

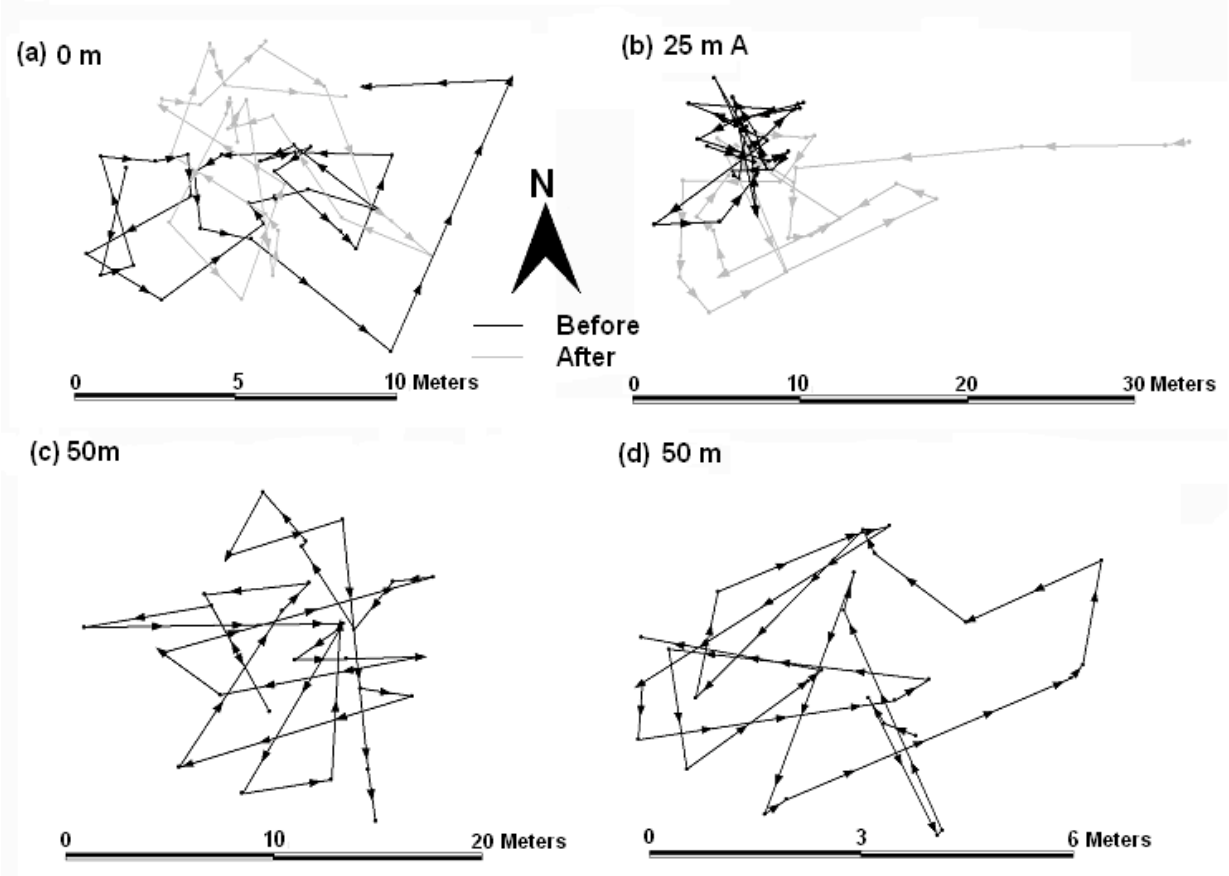


Figure 7. Movement maps of male Telfair's skinks on Round Island. The movement patterns for a skink which was not moved (a), a skink which was moved 25 m and returned to its original home range (b), a skink prior to being moved 50 m (c) and after it was moved 50 m (d).

There was no significant difference between the movement rate before and after translocation for the treatments 0 m and 25 m A (Fig. 7 and Table 6). However, for the treatments 50m and 25 m B the skinks moved less (Table 6).

Table 6. Summary of the mean movement rates and standard deviations before and after translocation of the skinks to different distances. Separate paired t-tests compare the movement rate before and after translocation. Movement rate is in metres per hour. Statistical significance indicated with bold.

Treatment	Before translocation/ mh^{-1}	After translocation/ mh^{-1}	*T*	*P*
0 m	0.93±0.13	0.86±0.1	1.958	0.98
25 m A	0.93±0.15	0.70±0.12	1.063	0.366
25 m B	0.99±0.11	0.55±0.07	4.909	**0.003**
50 m	0.95±0.11	0.61±0.12	4.572	**0.045**

Weight loss

Most skinks lost weight (Fig. 8 & Table 7). The greatest weight loss occurred due to either the combined effects of translocation and the backpack or just translocation (after, Fig. 8). Weight loss as a result of just the backpack was comparatively small (before, Fig. 8).

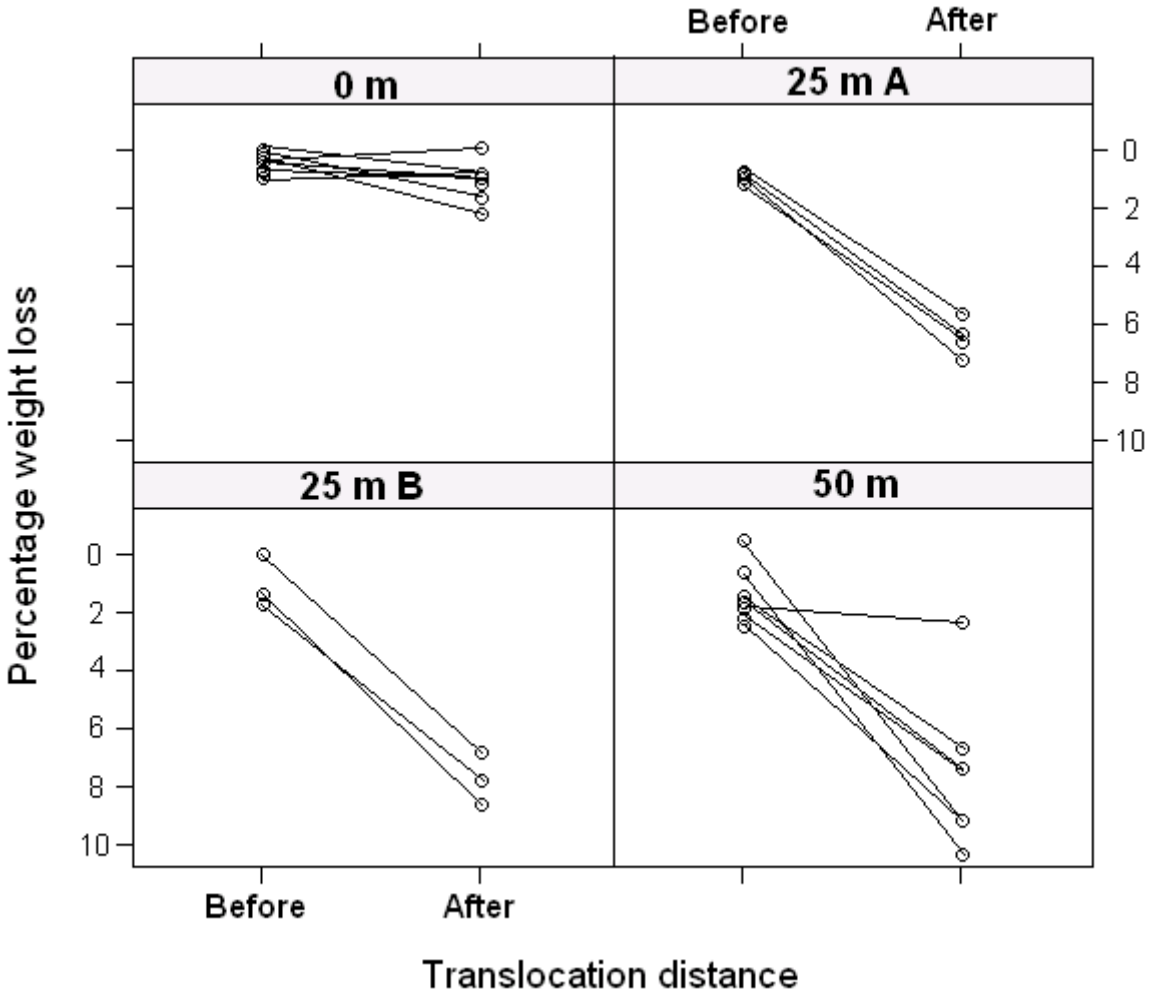


Figure 8. Percentage weight loss of the Telfair's skinks before and after they were translocated to varying distances. Before is the weight loss from the initial weight when first captured (27th March) and the weight prior to the skinks being translocated (3rd April) It is a measure of the effect of the backpack on the skinks' health. After is the weight loss calculated from before they were translocated (3rd April) to after they were translocated (10th April). This weight loss is therefore also a consequence of the translocation. Overall, significant weight loss only occurred in the skinks that were translocated, but not in those who were left in their original home range. 25 m A refers to the skinks that were moved 25 m and returned to their original home range and 25 m B to the skinks that established new home ranges.

Table 7. Summary of the mean percentage body weight loss and standard deviations before and after translocation. Separate paired t-tests compare skink body weight losses before and after translocation to different distances. Before translocation, is the percentage body weight loss from when initially captured to just prior to translocation. After translocation, is the loss experienced as a consequence of the backpack and the translocation. Statistical significance indicated with bold.

Treatment	Before translocation/ %	After translocation/ %	*T*	*P*
0 m	1.32±0.14	1.94±0.27	2.068	0.084
25 m A	1.78±0.1	7.28±0.32	17.375	**< 0.0001**
25 m B	1.05±0.53	7.74±0.53	4.831	**0.003**
50 m	1.89±0.38	7.72±0.95	17.375	**< 0.0001**

Behaviour

The frequency of the observed behaviours significantly varied before and after localised translocation when analysing all four groups together ($F_{5,237}$= 4.28, P=0.001)(Fig. 9). Hiding was generally the behaviour that differed most when analysing types of behaviours seperately for each group (Table 8).

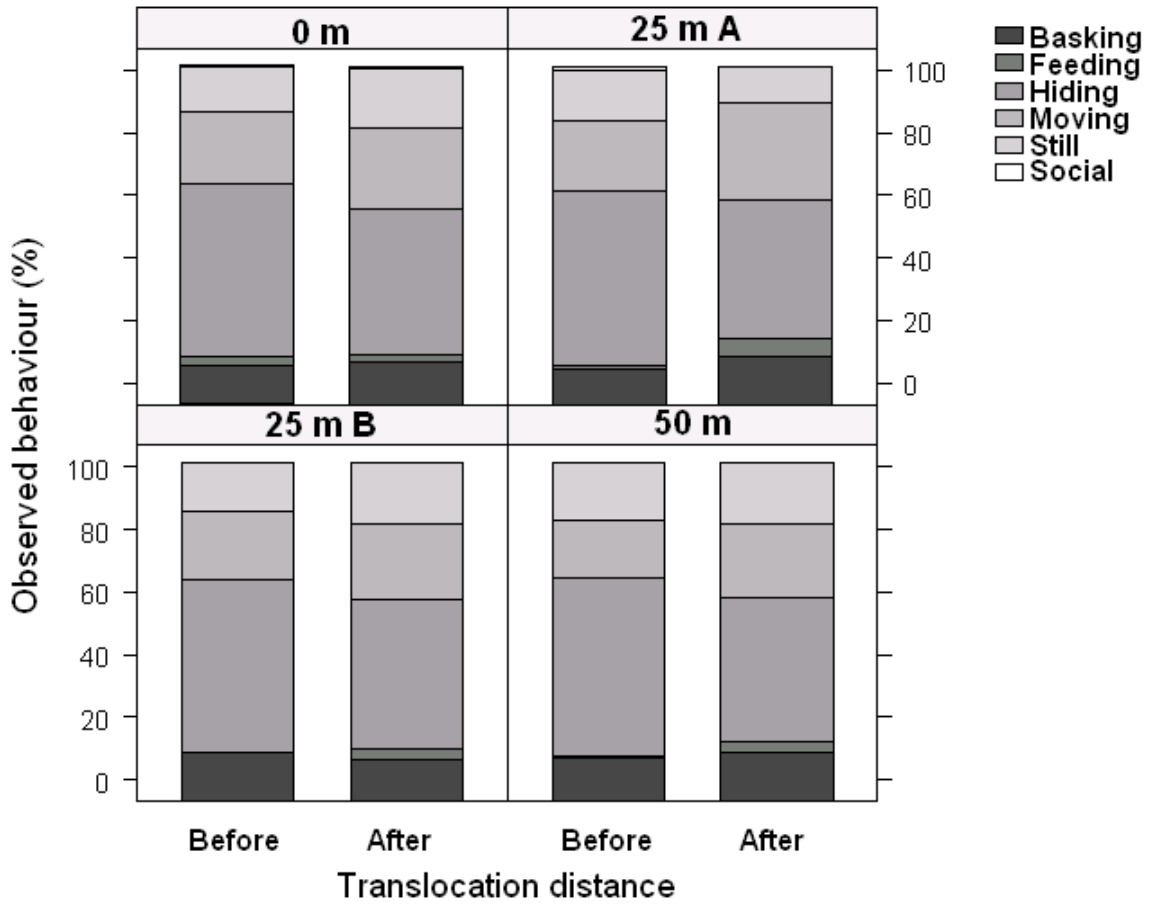


Figure 9. Behaviour of the Telfair's skinks before and after translocation to different distances. Percentages of observed behaviour were calculated as the proportion of the total number of particular behaviour observed for all the skinks.

Table 8 Summary of GLMs comparing the differences in the frequency of each behaviour before and after translocation at the different distances. d.f. = numerator degrees of freedom, denominator degrees of freedom. Statistical significance indicated with bold.

Treatment		Basking		Feeding		Hiding		Moving		Still		Social	
	d.f.	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
0 m	1,12	0.61	0.45	0.17	0.69	32.42	**0.0001**	0.5	0.49	0.76	0.4	0	1
25 m A	1,6	0.79	0.41	6.48	**0.044**	5.4	0.059	2.99	0.13	1.15	0.34	2.77	0.15
25 m B	1,4	0.13	0.73	2.77	0.17	17.92	**0.013**	0.1	0.77	0.14	0.73	0	1
50 m	1,12	0.48	0.5	4.08	0.066	18.8	**0.0009**	1.3	0.28	0.047	0.83	0	1

Substrate

Substrate choice varied significantly before and after localised translocation when analysing all four groups together ($F_{5,246}$= 182.8, P=0.001). The further they were translocated from their original home range, the more different was the frequency in chosen substrates (Fig. 10 & Table 9).

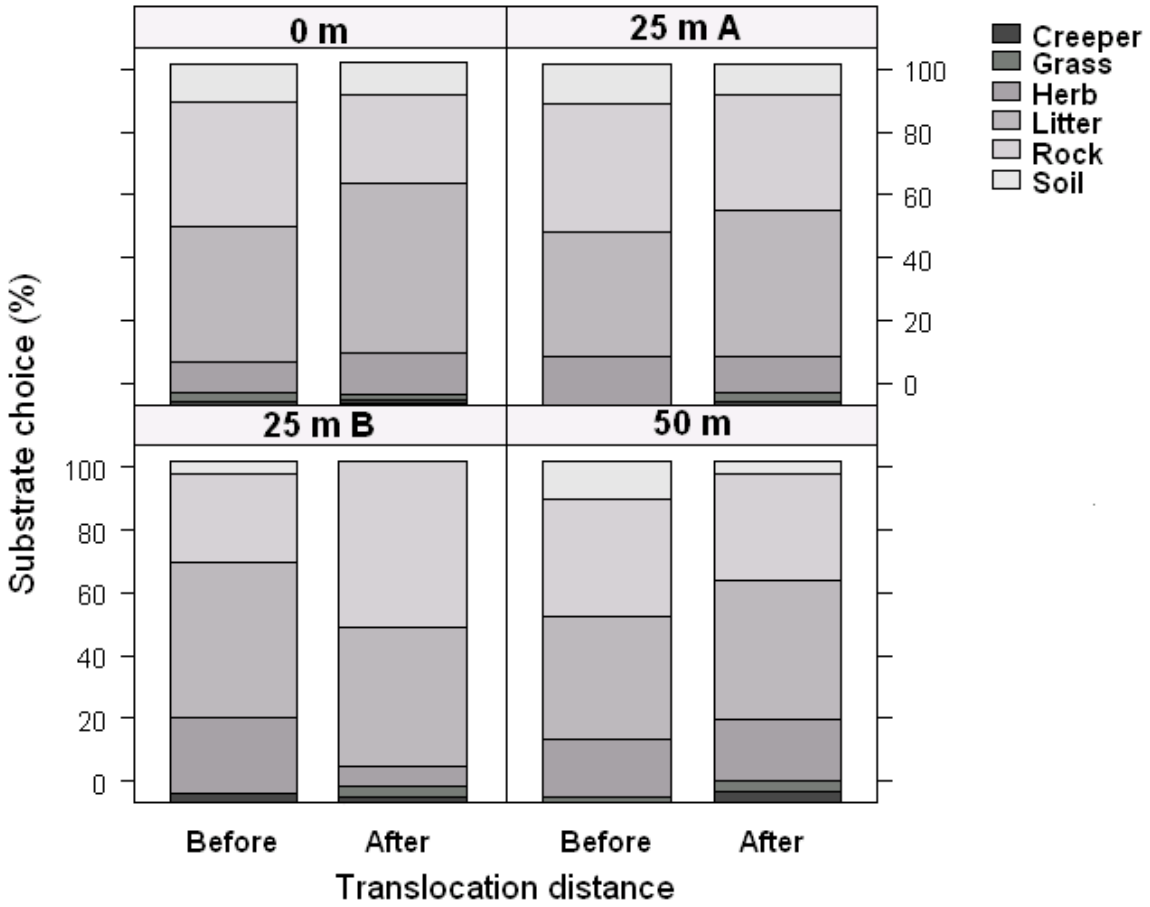


Figure 10. Substrate choice of the Telfair's skinks before and after translocation to different distances. Percentages of observed behaviour were calculated as the proportion of the total number of particular behaviour observed for all the skinks.

Table 9 Summary of GLMs used to compare the substrate choice before and after translocation at the different distances. d.f. = numerator degrees of freedom, denominator degrees of freedom. Statistical significance indicated with bold.

Treatment		Creeper		Grass		Herb		Litter		Rock		soil	
	d.f.	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
0 m	1,12	27.8	0.12	0.27	0.61	0.36	0.56	9.74	**0.009**	2.9	0.11	0.61	0.45
25 m A	1,6	19.8	1	0	1	3.14	0.13	9.7	**0.021**	1.03	0.35	4.42	0.08
25 m B	1,4	0.45	0.53	2.8	0.17	0.59	0.49	1.6	0.28	2.54	0.19	2.77	0.17
50 m	1,12	4.1	0.067	0.64	0.44	0.41	0.53	0.17	0.69	0.005	0.94	10.07	**0.008**

Exposure

Following localised translocation, the skinks selected different exposures types with different frequencies ($F_{4,205}$= 1197.44, P=0.001). The further they were moved from their original home range, the more variable was the frequency in chosen exposure (Fig. 11 & Table 10).

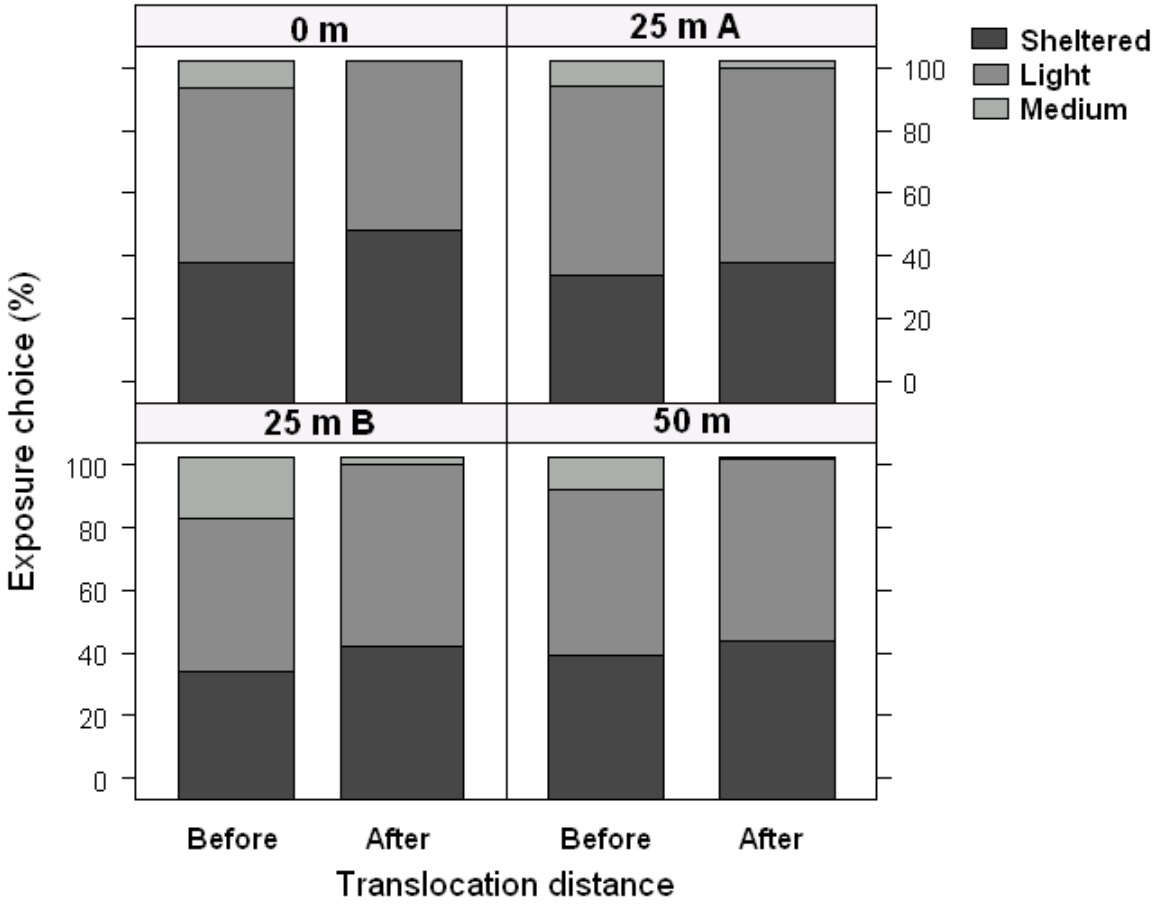


Figure 11. Exposure selection of the Telfair's skinks before and after translocation to different distances. Percentages of observed behaviour were calculated as the proportion of the total number of particular behaviour observed for all the skinks.

Table 10 Summary of GLMs comparing the exposure selection before and after translocation at the different distances. d.f. = numerator degrees of freedom, denominator degrees of freedom. Statistical significance indicated with bold.

Treatment		Sheltered		Light		Medium		High		Exposed	
	d.f.	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
0 m	1,12	6.84	**0.023**	0.10	0.75	195.7	**<0.0001**	0	1	0	1
25 m A	1,6	0.20	0.67	0.24	0.64	2.03	0.20	0	1	0	1
25 m B	1,4	0.40	0.56	1.11	0.35	1.95	0.23	0	1	0	1
50 m	1,12	1.52	0.24	0.05	0.83	17.9	**0.0012**	0	1	0	1

Discussion

The first-time use of radio tagging on Telfair's skinks has been an incite into their lifestyle on Round Island and Ile aux Aigrettes. The skinks were located mostly between open rocky areas among fan palms (*Latania loddigesii*), during both day and night on Round Island, and on the thick litter undergrowth in the shade of the hardwood forest on Ile aux Aigrettes. The male and female Telfair's skinks on Round Island had similar home range sizes, while those on Ile aux Aigrettes differed. Home range sizes were ten times bigger on Ile aux Aigrettes than on Round Island. In general, skink behaviour between the islands varied little. However, Ile aux Aigrettes skinks basked more and hid less than those on Round Island. The local translocation experiment showed that the critical homing capacity for Telfair's skinks is around 25 m. The use of the transmitters and backpacks were the likely cause of weight loss in some skinks, but the majority was due to the translocation.

Home range size and home range overlap

Male and female Telfair's skinks did not have distinct or exclusive home ranges; home ranges overlapped greatly on both islands both inter-and intra-gender. Within an individual skink's home range, up to 32 conspecifics were sighted at the same time. The Telfair's group living social structure is comparable to that of the South African lizard, *Cordylus cataphractus* (Pernetta *et al*. 2005; Visagie *et al*. 2002), whereby several skinks of different gender and age live in the same areas, that is overlapping home ranges.

Home ranges of male and female skinks overlapped, and several marked females were frequently sighted in the vicinity of tagged males. Female home ranges overlapped more with males' on Ile aux Aigrettes than on Round Island (64 % vs. 41 % overlap, respectively). The larger home range of male skinks (nearly 10 times bigger) on Ile aux Aigrettes than Round Island explains this. In some instances, female home ranges were completely enveloped by male home ranges.

The 90 % fixed kernel home range estimates suggested that on Round Island, average home ranges were 203 m^2 for male skinks and 214 m^2 for females, compared to 1858 m^2 and 1076 m^2, respectively, on Ile aux Aigrettes. On Ile aux Aigrettes home range size was more than 9 times that of Round Island skinks (Appendices 1 & 2). At higher skink density, as on Round Island (120 skinks/ha. compared to 7 skinks/ha. for Ile aux Aigrettes), resources are assumed to be scarcer as competition is higher (Richards 2007). Accordingly, skinks on Round Island should have larger areas to forage (Christian & Waldschmidt 1984; Huey *et al*. 1989; Kelt & Van Vuren 2001; Mace & Harvey 1983; Mysterud *et al*. 2001; Reiss 1988). This contrary result with respect to home range size, suggests that the home ranges of the Telfair's skink are linked to population density, not resource availability. If resources are scarce due to a higher skink density, resource acquisition should be more secure and higher if skinks protect them. Alternatively, small home range size might be a a behavioural adaptation to reduce energy expenditure in the harsh Round Island climate; and thus survive with limited resources (Christian *et al*. 2003). The larger home ranges on Ile aux Aigrettes, where resources are plentiful and the climate is less extreme under the hardwood canopy, supports this.

Richards (2007) found that the translocated Telfair's skinks on Ile aux Aigrettes shifted towards a diet of native fruits, utilising available resources in their new environment and potentially assisting in seed dispersal. Furthermore, their body condition improved, compared to their initial conditions when first released to Ile aux Aigrettes (Richards 2007). This could be a reason, why the Ile aux Aigrettes skinks have larger home ranges. They need to incorporate more areas depending on the fruits they feed on. Thus their home range size may differ at different times of the year depending on food availability.

In their review about lizard home range sizes (Perry & Garland 2002) found that male lizards generally have larger home ranges than females. In our study, this was also found for the Telfair's skink on Ile aux Aigrettes, but not but for the skinks on Round Island, where home range size was similar for the two sexes. It is possible that due to the higher skink density and the harsher climate on Round Island, males were unable to manage larger home ranges to include more females (Osterwalder *et al*. 2004). We infer that the home ranges of the Ile aux Aigrettes skinks are representative of under-populated populations whereas the Round Island situation represents the outcome of an over population scenario following the density compensation theory (Rodda & Dean-Bradley 2002; Rodda *et al*. 2001). In accordance with the ideal free distribution theory (Fretwell & Lucas 1970), at low population

density all individuals are able to occupy an optimal home range area, which decreases with increasing density.

Differences in Telfair's skink ecology from Round Island and Ile aux Aigrettes

With larger home ranges, the Ile aux Aigrettes skinks were more active than those on Round Island. This is in line with findings for other lizard species (Nowak *et al*. 2002; Reinert & Rupert 1999; Sullivan *et al*. 2004), where translocated animals moved more than non-translocated animals. Contrary to Round Island where both sexes moved similar amounts, on Ile aux Aigrettes the males moved almost three times more than the females. This could be explained by energetic needs, whereby females usually restrict their movements to preserve energy for reproductive demands (Bauwens & Thoen 1981; Brana 1993; Brodie 1989; Cooper *et al*. 1990; Weiss 2001), whereas males structure their movements and home ranges according to female availability, thereby maximising reproductive success. Males are thus more disposed to moving. On Ile aux Aigrettes, the encounter rate of females, is much lower due to their lower density.

Ile aux Aigrettes skinks spent more time basking than Round Island ones. The well-developed hardwood canopy on Ile aux Aigrettes limits the amount of light falling on the forest floor, so that skinks were required to bask longer in order to thermoregulate efficiently. Skinks were often observed basking in a solitary ray of sun penetrating through the canopy. In contrast, the open nature of Round Island's palm forest meant that skinks could thermoregulate quicker. Thermal stress as a result of overheating was a problem.

Habitat differences also explain the highly significant difference in hiding behaviour observed between the islands. The dense forest canopy protects Ile aux Aigrettes skinks during the hottest parts of the day, whereas Round Island skinks require shade, which is limited. The high density of skinks on Round Island means that skinks have to forage more, as competition is high, thereby were more active. Round Island skinks were more opportunistic and fed at every opportunity (pers obs.), whereas the Ile aux Aigrettes skinks fed less often. However, they were healthier and bigger in size (Richards 2007). The greater skink density on Round Island resulted in more observations of social behaviour on this island compared to Ile aux Aigrettes.

Substrate choice consistently differed between islands, however not between genders on an island. This can be attributed to the different relative amount of substrates available on the two islands. Round Island, a volcanic offshore island has a harsher climate and is predominantly composed of rock, whereas Ile aux Aigrettes, an inshore coralline island has

mainly limestone coral as bedrock. Regardless, both rock and coral were selected more frequently than other substrates. The Telfair's skink preference for open rock or coral is a trait shared with many other reptile species (Christian & Tracy 1984; Diaz *et al*. 2006; Huey 1991; Huey *et al*. 1989; Sabo 2003; Schlesinger & Shine 1994; Webb & Shine 2000).

Telfair's skink preference for ferns and herbs supports earlier findings that they select areas on the basis of structural and vegetative characteristics, often choosing microhabitats with increased vegetation cover at both 50 and 100 cm above ground level (Pernetta *et al*. 2005). Litter is a favoured substrate for skinks on both islands. It provides ideal camouflage to escape detection by predators and to ambush prey. These results suggest that a variety of substrates of different structures are need by the Telfair's skink.

Levels of chosen exposure by the skinks differed between islands not between genders on an island. The different plant communities offering different types of shelter explain this. The fragmented nature of the palm forest meant that skinks were more likely to be exposed to direct sunlight when moving and foraging, whereas, the dense Ile aux Aigrettes forest provided continuous shelter.

Effect of localised translocation on Telfair's skink

Homing capacities of Telfair's skink

Since the Telfair's skink is a relatively sedentary species according to the criteria of (Berry 2006; Sumner 2006; Wymann & Whiting 2002) selection for a generalised spatial sense of orientation would seem unlikely. However, our results suggest that there is an effect of distance of translocation on returning success. Four out of the seven lizards that were displaced 25 m from their home range returned to their original home range from presumably unfamiliar release localities, whereas none of the skinks displaced 50 m returned. None of the control skinks left their original home range.

From these results, we tentatively infer two things. Firstly, the costs and risks of travelling through unfamiliar habitat and the home range of conspecifics to return to a specific location are outweighed by the benefits, in terms of survival and reproduction, offered by a familiar home range. Secondly, the ability to return to their original home range in a relatively short period (day range sometimes) suggests that they have cognition and can use familiar and unfamiliar views of landmarks as reference points to guide them home (Jenssen 2002). Nevertheless, this appears restricted to around 25 m.

The fact that some skinks established new home ranges in the area 25 m away suggests that the translocation sites offered equally suitable microhabitat requirements, and thus the costs of returning would not outweigh the benefits. Alternatively, the new area may have provided more open areas for hunting which are preferred for sit–and-wait predators (Denno *et al*. 2005; Shepard 2007) or an alternative reason to returning could be simple individual choice differences.

Home range size and movement

We think that the possible ability of the skinks moved 25 m away to recognise familiar landmarks was reassuring and thereby did not significantly alter their behaviour or movement rate (Baker 1978). Conversely, it is likely that those skinks moved 50 m away were unable to recognise familiar landmarks and consequently hid for most of the time. This behaviour alteration significantly restricted their home range size and movement rate, as found with Gila monsters (Sullivan *et al*. 2004). This change in behaviour and movement could also be a result of stress which we anticipate to be more acute in an unfamiliar area (Letty *et al*. 2000). Our results contradict those of other reptile studies, where translocated individuals moved more than non-translocated individuals (Nowak *et al*. 2002; Reinert & Rupert 1999; Sullivan *et al*. 2004).

Weight loss

Studies on radio telemetry lack accounts of adverse tag effects (Kenward 2001). Overall, we found that tagging and translocation had a negative effect on the skinks, in terms of weight loss. Backpacks may have hindered prey capture efficiency and reduced mobility and dexterity (Letty *et al*. 2000). However, our finding that weight loss was much higher for translocated skinks that non translocated ones suggest that stress due to translocation was the more adverse factor here. Although some skinks experienced skin abrasions where the backpack was attached, we conclude that radio tagging is an appropriate technique for studying the Telfair's skinks spatial ecology.

Differences in Telfair's skinks behaviour, substrate choice and exposure following localised translocation

Independent of the distance the skinks were translocated, behaviour observed, substrate and exposure chosen did not change significantly after translocation. The frequency of hiding decreased significantly for most skinks. This could be explained by the skinks becoming

accustomed to the backpacks and regular tracking, or that the backpacks hindered their ability to hide amongst the leaf litter, and were thus more apparent. We thereby conclude that localised translocation had negligible effects on the behaviour, substrate and exposure chosen by the skinks.

Our study showed that there was no predictable pattern in the Telfair's skinks home-range size, and social organisation as in sea Iguana as proposed by Stamps (1983) depending on which island the study was carried out. This highlights the importance of investigating the effect of different habitat types on the home range of an animal (Perry *et al*. 2002). Home range size may differ significantly between the seven habitat types on Round Island.

We learned from the translocation experiment, that the Telfair's skinks have homing capacities presumably based on familiar landmarks that work only for a distance of 25 m or less. Localised translocation had a detrimental impact on the skinks as it resulted in weight loss. Thus, we recommend only using the healthiest animals for translocation. Encouragingly, skinks' high plasticity and adaptability to new habitats makes them suitable for translocation. We conclude that translocating skinks to colonise new habitat, or to rapidly increase distribution range would not adversely impact them and that they would be able to cope and adapt easily. Our work on their dietary preferences supports this. This would enable conservation managers to expand the skink's distribution which would help reduce high densities as a known cause of decreased female skink fecundity (Hasegawa 1997) thereby impacting population growth. Our study provides evidence that the Telfair's skink is a highly adaptable species that can cope with translocation, adapt to its new environment and even thrive in it.

If the long term monitoring of the translocated skinks is positive, we could start thinking of the future use of Telfair's skinks as an analogue to the newly described extinct large skink on Réunion (Arnold & Bour 2008). The closest living relatives of the genus *Leilopisma* occur on New Caledonia (*Emoia impar*) and in New Zealand (*Emoia physicae*) (Arnold 1980; Austin & Arnold 2006). Pristine Mauritius had two *Leiolopisma* species: *L. telfairii* and *L. mauritiana* (Arnold 1980) and Reunion island, found at 200 km to the southwest of Mauritius (see Fig. 1) had one species the *Leiolopisma cecilia* (Arnold & Bour 2008). The two last species are now extinct with only the Telfair's skinks surviving.

Leiolopisma mauritiana was one of the largest skinks known (Arnold 1980). It reached an estimated snout-vent length (Svl) of around 340 mm, compared with 170 mm for the largest Round Island *L. telfairii* and an estimated 200 mm for Mauritian sub-fossils of this species, both species were sympatric (Arnold 1980). *Leiolopisma ceciliae* was an intermediate

sized skink and robustness, compared to the two Mauritian species (Arnold & Bour 2008). It was most similar to *L. telfairii* but differed in larger maximum size with a Svl of at least 175 mm (Arnold & Bour 2008) and was more closely related to the giant *L. mauritiana* rather than to the morphologically more similar *L. telfairii* (Austin & Arnold 2006). *Leiolopisma ceciliae* may have colonised Réunion from Mauritius, thus illustrating the 'island hopping' hypothesis. With its similar size and characteristics and its high plasticity the Telfair's skink would be the prime candidate to be translocated to Réunion, where no skink species have survived and recreate lost plant animal interactions. With its similar characteristics (size, genus), high adaptability and plasticity Telfair's skink would be the prime candidate to be translocated to Réunion, where no skink species have survived. There it may recreate lost plant-animal interactions and even make ecosystem more resistant to invasion by exotics plants. As we found that the Telfair's skink increases the percentage germination of native species and reduces the survivorship of exotic species (see chapter 4). Nevertheless, prior to future translocations, it is recommended to conduct more detailed studies of the species' biology and ecology and its recipient habitat (Dodd & Seigel 1991; IUCN 1996).

Finally, radio telemetry proved an appropriate technique for studying the Telfair's skink spatial ecology. Despite the cost limitations, we found that the benefits of telemetry were high and adverse effects negligible.

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Appendix I. Home-range size before and after localised translocation, and morphometrics of tracked male and opportunistically sighted female Telfair's skinks (*Leiolopisma telfairii*) on Round Island. Treatment is the distances that the male skinks were moved for the within island translocation experiment. * denotes female skinks disregarded from analyses due to insufficient locations (< 10 locations).

Skink ID	Sex	SVL/mm	Weight/ g	Number of locations	Home range area/m²	Treatment /m	Home range area after translocation/ m²
TM01	Male	146	99	28	285	50	24
TM02	Male	153	110	28	53	25	201
TM03	Male	151	124	28	144	0	153
TM04	Male	146	93	28	177	25	64
TM05	Male	156	125	28	311	0	146
TM06	Male	136	108	28	165	50	76
TM07	Male	149	115	28	332	25	109
TM08	Male	146	155	28	302	0	172
TM09	Male	169	175	28	316	50	65
TM10	Male	142	97	28	506	0	141
TM11	Male	150	120	28	238	25	43
TM12	Male	165	135	28	321	50	117
TM13	Male	148	97	28	152	25	168
TM14	Male	156	119	28	473	50	123
TM15	Male	153	104	28	50	0	112
TM16	Male	147	116	28	105	0	73
TM17	Male	151	119	28	76	25	93
TM18	Male	137	123	28	33	50	38
TM19	Male	149	99	28	54	50	95
TM20	Male	174	173	28	89	0	41
TM21	Male	166	138	28	78	25	32
Mean		**152**	**121**	**28**	**203**		
TF01	Female	120	58	10	70		
TF02	Female	120	48	12	132		
TF03	Female	121	53	14	242		
TF04	Female	122	64	13	159		
TF05*	Female	122	50	8	176		
TF06	Female	122	52	12	247		
TF07	Female	123	69	14	346		
TF08	Female	123	157	16	378		
TF09	Female	123	51	18	326		
TF10*	Female	123	53	4	388		
TF11*	Female	124	69	6	351		
TF12	Female	125	62	9	192		
TF13	Female	125	62	12	347		
TF14	Female	126	65	13	368		
TF15	Female	126	58	16	154		
TF16	Female	126	51	25	212		
TF17	Female	127	110	14	176		
TF18*	Female	127	50	8	54		
TF19	Female	127	87	22	133		
TF20	Female	128	74	11	144		
TF21*	Female	128	60	7	97		
TF22*	Female	128	55	8	75		
TF23	Female	128	55	12	106		
TF24	Female	128	54	14	111		
TF25	Female	128	76	16	193		
Mean		**125**	**66**	**13**	**207**		

Appendix II. Home-range size and morphometrics of tracked male and opportunistically sighted female Telfair's skinks (*Leiolopisma telfairii*) on Ile aux Aigrettes. * denotes female skinks disregarded from analyses due to insufficient locations.

Skink ID	Sex	SVL/mm	Weight/g	Number of locations	Home range area/m²
TM01	Male	158	150	18	5722
TM02	Male	153	136	18	1015
TM03	Male	161	126	18	980
TM04	Male	155	116	18	1441
TM05	Male	145	103	18	1334
TM06	Male	172	172	18	432
TM07	Male	173	208	18	5971
TM08	Male	174	207	18	1187
TM09	Male	162	143	18	633
TM10	Male	171	165	18	1174
TM11	Male	166	154	18	1664
TM12	Male	167	178	18	748
Mean	**Male**	**163 (SE)**	**155 (SE)**	**18 (SE)**	**1858**
TF01	Female			9	2785
TF02	Female			5	1169
TF03	Female			5	650
TF04	Female			6	67
TF05	Female			7	418
TF06	Female			8	1195
TF07	Female			9	2854
TF08	Female			7	826
TF09	Female			6	116
TF10	Female			5	1485
TF11*	Female			4	677
TF12	Female			5	267
Mean				**6 (SE)**	**1042**

CHAPTER 6

General discussion and conclusion

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Mauritius harbours unique endemic flora and fauna communities in which birds and reptiles take key positions (Myers *et al*. 2000). Unfortunately over the past 400 years, Mauritian ecosystems have been heavily degraded (Cheke & Hume 2008). Initially, overexploitation of particular species caused a series of plant and animal extinctions. Consequently, many co-evolved plant–animal interactions were disrupted, which may have led to lost ecosystem services and functions (Arnold 1979; Olesen & Valido 2003). Many of the endemic and native flora are critically endangered and continue to be threatened with extinction. Today, most of the native fauna and flora are restricted to mountain tops, cliffs, conservation management areas (CMAs), and offshore islands. Despite their often small size, some of these islands support many endemic, threatened species, and hence are of significant conservation value (Jones 1993). One such island is Round Island, which has never been invaded by rats and hence has retained most of its reptile community (Arnold 2000).

Some believe, Round Island to have reached its carrying capacity in terms of reptile population size for some species such as the Telfair's skink and the Bojer's skink (North *et al*. 1994). Nevertheless, they remain small and therefore vulnerable to stochastic and anthropogenic events like cyclones and tsunamis (Caughley 1994; North *et al*. 1994), or an accidental introduction of a predatory or competitive species, such as rats or house geckos (Bullock 1986). Insurance against such a disaster can be mitigated by establishing populations in alternative suitable recipient sites, such as other offshore islands free of potential predators. Translocation could help guarantee the persistence of the species, in addition to recreating lost interactions between the native fauna and flora (e.g. seed dispersal). However, successful translocation projects are only feasible with a sound scientific knowledge of the biology and ecology of wild populations (Dodd & Seigel 1991; IUCN 1996). The overall aim of this thesis was to provide the required scientific information to guide Round Island reptile conservation.

We found that the different reptile species do not occur in all the habitats of Round Island, with the exception of the Telfair's and Bojer's skinks. This suggests that these two species are more adaptable to different habitats, whereas, the other species are more specific in their requirements.

According to our population estimates, most reptile populations on Round Island seem large enough not to be immediately threatened by adverse genetic and demographic effects. No species appears in immediate danger of extinction, as all have sustainable populations. These estimates suggest that the populations of all Round Island reptile species are large enough to undergo translocation, without leaving the source populations non-viable and vulnerable to adverse genetic effects. Despite claims that the island has reached its carrying capacity in terms of reptiles, we believe that this is not the case as more affable microhabitat will be made available, enabling the population sizes to increase in conjunction with the continuing restoration work.

The diet composition of a reptile species is a crucial aspect of its ecology. Our results confirm the significance of invertebrates in the lizards' diet, as well as the specialised nature of the Keel-scaled boa, with the adult feeding exclusively on birds and reptiles and the juvenile exclusively on reptiles. Since the boa is a specialist species and the top predator in the Round Island food web, we recommend that it should not be translocated until there is a well establish and abundant reptile and bird population in the recipient habitat. With regards to lizards, our results suggest a high level of opportunism and generalisation in the selection of prey, and that changes in the abundance of prey. The studied species have an ample food supply and probably select prey that provide the most energy, and are easier to capture and consume.

Reptiles similar in body size, microhabitat use and food choice are more likely to compete for resources. There are two groups of reptiles on Round Island with high overlap in the niche dimensions diet, substrate used and foraging mode. One group is composed of the Telfair's skink, Bojer's skink and Durrells' night gecko, whereas the Ornate day gecko and Guenther's gecko belong to a second group. The lack of consistent patterns of food item utilisation within and between species, suggests that there may have been negligible intraspecific and interspecific competitive interactions in terms of diet in the Round Island reptile assemblage.

With respect to translocation, since invertebrates are the most important diet constituent of adult and juvenile Round Island lizards, we recommend that recipient sites should have a rich invertebrate fauna. As juvenile and adult conspecifics do not compete for the same food resources, both ages could be translocated simultaneously. Nevertheless, it would be better to translocate larger individuals of a species, as they are less restrictive in diet choice and so can adjust their diet to consume the new food items in their environment. Consequently, survival chances are likely to be greater.

We recommend to translocate omnivores, prior to specialist species. If the recipient site has an abundant food supply, also species with overlapping diets may be translocated simultaneously. Based on our findings, we believe that if a recipient site were to have a replicated Round Island herpetofauna established, then the small reptile species should be translocated first, allowed to establish viable populations, and then larger ones can be introduced. Regardless, the recipient site's species should be carefully considered as assumed impacts are not necessarily predictable. For example, we have found that the three largest reptiles have high electivity indices for land birds. Thus, careful evaluation should be taken prior to the translocation of these reptile species to areas with endangered land birds. The observed high electivity for land birds may be problematic for Mauritian fody (*Foudia rubia*) a critically endangered weaver bird, which will be translocated to Round Island in the near future as a means of expanding their distribution.

We found that translocated Telfair's skinks fulfilled their role as a seed disperser. They spread seeds, regardless of whether they are of exotic, native or endemic origin. Fortunately, they increased the percentage germination of endemic species, while decreasing the survivorship of the exotic species. The translocation of the Telfair's skinks to their historic distribution or their use as analogues for extinct species should thereby re-establish ecosystem functions with positive cascading effects. We found that the reintroduction of lost reptile species can make ecosystems more resistant to invasions. This would benefit restoration efforts in which the ultimate goal is to establish self-sustaining ecosystems.

We have a better understanding about the population size and the diet of the Round Island reptiles, and conclude that the Telfair's skink is thriving following its translocation to Ile aux Aigrettes. As a result we can give some informed conservation management suggestions. However, caution and restraint is necessary when considering future translocations, based on only this information. Translocation can only be assessed following long term monitoring of the translocated population. The Telfair's skink is a very adaptable species, which may have made its translocation easier. However, we still have to see if they can find suitable sites to lay their eggs and reproduce; as the main goal of the translocation is that they found new self sustaining populations.

We think that for the other Round Island reptile species, with the exception of the Bojer's skink, which is as adaptable as the Telfair's skink, more in-depth studies should be conducted prior to translocation; studies investigating for example egg site selection, microhabitat demand, community and size structure and substrates use should be determined. A better understanding of the requirements of these reptiles would be obtained, enabling the

selection of a more suitable recipient habitat. Nevertheless, we recommend translocating the lizards to habitats with a diverse and abundant invertebrate fauna. We believe that it would not be problematic to translocate different species at different ages to the same recipient habitat as long as food is not limited and available throughout the different seasons. Without abundant food, competition for food resources is inevitable. Furthermore as the Keel-scaled boa, Guenther's gecko and Telfair's skink are very selective of medium-sized bird and smaller reptiles; it would be counter productive to translocate them to recipient habitats where medium-sized birds and smaller reptile conservation is underway.

We conclude that translocation is a useful tool to conserve reptiles species as long as it is done with detailed studies about the biology and ecology of wild populations.We found that translocations and thus the re-creation of lost plant-animal interactions can have positive cascading effects. Thus we recommend carrying out flora and fauna restoration programs in conjunction as they are conducive to each other. For example, when planting native and endemic flora, the introduction of their co-evolved grazers and seed dispersers should be considered. Restoring these lost plant-animal interactions is likely to stabilise the ecosystem, increasing the probability of the success of restoration efforts and the self–sustainability of the restored ecosystem.

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Summary

In this thesis, we provided the required scientific information to guide Round Island reptile conservation. In addition, data on the basic biology of the reptiles was compiled and the first study on the translocation of the Telfair's skinks to Ile aux Aigrettes was conducted.

Chapter 2 contained the first year long study of the population estimates and distributions of the entire reptile assemblage of Round Island, accounting for spatial and temporal effects. We provided the first population estimates of the Round Island reptile species at two different stages of development (adult and juvenile), based on a study period of twelve months and in all the seven habitats of the island. Since some of the reptiles species differed in behaviour, we report that the best method to estimate reptile populations is to use a combination of approaches, namely belt transects, distance sampling and total removal quadrats. Combining these methods will better suit the detection of more cryptic animals, thereby providing more accurate estimates of the different reptiles' populations.

Chapter 3 presented the variation in dietary preferences of the entire reptile assemblage of Round Island. We discovered that the different reptile species, and the adult and juveniles of each species have different diets, which varies according to the month. Furthermore, we found the same trend in the number of prey items chosen, electivity indices and dietary niche overlap. The Keel-scaled boa, the only snake, had a different diet composition, electivity index and dietary niche overlap to the lizards. An additional finding was that the diet composition, number of prey chosen, electivity index and dietary niche overlap was dependent on the size and weight of the reptile. Since invertebrates constituted such a large part of the lizard's diet, we concluded that if they are translocated, it should be to an island with an abundant invertebrate fauna. In general, the translocation of species should be favoured because of their ability to vary their diet. The omnivore species are particularly suited to translocation, as they can adapt their diet, and in that regard, are prime candidates for translocation.

Chapter 4 showed the first experimental evidence that Telfair's skinks gut passage can play an important role in the germination rate and survivorship of endemic, native and exotic fleshy fruits growing on Round Island. We found that the percentage germination of the three endemic species increased, while the survivorship of the exotic species decreased. The main factors responsible for these effects were the gut passage and subsequent deposition in skink faeces. The results show that contrary to what was expected, translocation of the Telfair's skinks to new islands should not have a negative effect but a positive one, by

reducing exotic fleshy fruit species survivorship. Our results present serious implications for the conservation and restoration management of ecosystems on oceanic islands.

Chapter 5 documented the first telemetry study on the Telfair's skinks (*Leiolopisma telfairii*) and comparison of the skink following their translocation to Ile aux Aigrettes. We found that home range size and movement increased for the translocated population on Ile aux Aigrettes compared to the original population on Round Island. The homing capacities of male adult Telfair's skinks were limited to 25 m from their original home range. The results show that the skinks were affected by translocation. This provides us with better information to ameliorate this management tool. Although studies spanning multiple decades may be needed to determine whether translocation of the Telfair's skinks are ultimately successful given their life-history traits, this study is nonetheless a useful contribution.

Zusammenfassung

In dieser Arbeit untersuchten und quantifizierten wir verschiedene Aspekte der Nahrungszusammensetzung und des Nahrungsnetzes der gefährdeten Reptiliengemeinschaft auf Round Island (Mauritius). Zusätzlich untersuchten wir, was für einen Effekt eine Darmwanderung durch Telfair Skinke auf die Keimung der Samen von Pflanzen mit fleischigen Früchten hat. Schliesslich evaluierten wir, wie sich eine Umsiedlung von Telfair Skinken von Round Island auf die Ile aux Aigrettes auf das Verhalten dieser Reptilien auswirkt.

In **Kapitel 2** beschreiben wir, wie wir die Populationsgrösse sämtlicher Reptilienarten und deren Verteilung auf Round Island geschätzt haben. Dabei haben wir sowohl räumliche als auch zeitliche Effekte miteinbezogen. Dies ist die erste Studie, die Schätzungen der Populationsgrösse der Reptilien auf Round Island in zwei verschiedenen Entwicklungsstadien (Juvenil und Adult) beschreibt. Diese Schätzungen basieren auf Erhebungen während eines Zeitraumes von 12 Monaten in allen sieben existierenden Habitaten der Insel. Dabei erarbeiteten wir eine neue Methode, um die Grösse von Reptilienpopulationen in ökologisch empfindlichen Gebieten zu schätzen. Diese neue von uns vorgeschlagene Methode basiert auf einer Kombination zweier herkömmlichen Methoden, der „belt-transect"-Methode und der „total removal quadrats"-Methode. Diese neue Methode ermöglicht genaue Schätzungen der Populationsgrössen, nicht nur von häufig vorkommenden, sondern auch von seltenen Arten. Im Gegensatz zu anderen Methoden ist die von uns vorgeschlagene, neue Methode weit weniger destruktiv.

In **Kapitel 3** präsentieren wir die Nahrungspräferenzen aller auf Round Island vorkommender Reptilienarten. Die Nahrungszusammensetzung, Elektivität und der „diet overlap" variierten nicht nur zwischen den verschiedenen Reptilienarten, sondern auch zwischen den Entwicklungsstadien (Juvenil vs. Adult) und Monaten. Als Top-Prädator des Nahrungsnetzes unterschied sich die Keel-scaled Boa von den Echsen in der Zusammensetzung der Nahrung, der Elektivität sowie im „diet overlap". Wir fanden heraus, dass die Grösse und das Gewicht der Reptilien einen Einfluss auf die Nahrungszusammensetzung, die Anzahl an verschiedenen Nahrungsbestandteilen, die Elektivität sowie auf den „diet overlap" hat. Die Diät der Echsen bestand zum Grossteil aus Invertebraten. Für zukünftige Umsiedlung-Projekte schliessen wir, dass eines der Hauptkriterien des neuen Habitats eine ausreichend vorhandene Invertebraten-Fauna sein muss. Aufgrund ihres Spezialisierungsgrades kann generell gesagt werden, dass sich grössere

sowie omnivore Reptilienarten besser für eine Umsiedlung eignen als kleine oder spezialisierte Arten.

Kapitel 4 liefert zum ersten Mal experimentelle Hinweise darauf, dass die Keimungsrate von Samen und das Überleben von Pflanzen mit fleischigen Früchten unterschiedlich durch die Darmwanderung durch Telfair Skinke (*Leiolopisma telfairii*) beeinflusst wird. Dabei unterscheiden sich endemische, einheimische und exotische Pflanzenarten. Wir konnten zeigen, dass sich der Prozentsatz erfolgreicher Keimungen der drei endemischen Pflanzenarten durch die Darmwanderung erhöhte, während das Überleben der exotischen Arten vermindert wurde. Die Hauptgründe für diese Effekte waren die Darmwanderung sowie die darauffolgende Ablagerung im Echsenkot. Diese Resultate zeigen, entgegen den Erwartungen, dass sich die Umsiedlung von Telfair Skinken auf andere Inseln nicht negativ, sondern positiv auf die Vegetation auswirkt, indem das Überleben exotischer Pflanzenarten reduziert wird. Unsere Resultate haben Implikationen auf das Naturschutzmanagement und die Restaurierung von Insel-Ökosystemen und heben die wichtige Rolle einheimischer, frugivorer Echsen in solchen Ökosystemen hervor.

In **Kapitel 5** berichten wir von einer vergleichenden Telemetrie-Studie, in welcher wir die Auswirkungen der Umsiedlung von Telfair Skinken von Round Island nach Ille aux Aigrettes untersuchten. Wir fanden heraus, dass sich der Bewegungsradius der Skinke in der umgesiedelten Population vergrösserte im Vergleich zu der ursprünglichen Population. Die Fähigkeit adulter, männlicher Telfair Skinke zu ihrer „home range“ zurückzukehren, war limitiert auf ungefähr 25 Meter. Diese Resultate zeigen, dass sich das Verhalten der Telfair Skinke nach der Umsiedlung veränderte, um sich an das neue Habitat anzupassen. Die Anpassungen manifestierten sich in einer Vergrösserung der „home range“ und des Bewegungsradiuses. Diese Studie liefert wertvolle Informationen für die Umsiedlung von Reptilien und zeigt, dass Telemetrie eine geeignete Methode für die Evaluation von Umsiedlungs-Projekten ist. Trotzdem werden zusätzliche, detailliertere Langzeitstudien benötigt, um heraus zu finden, ob die Umsiedlung der Telfair Skinke erfolgreich war.

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